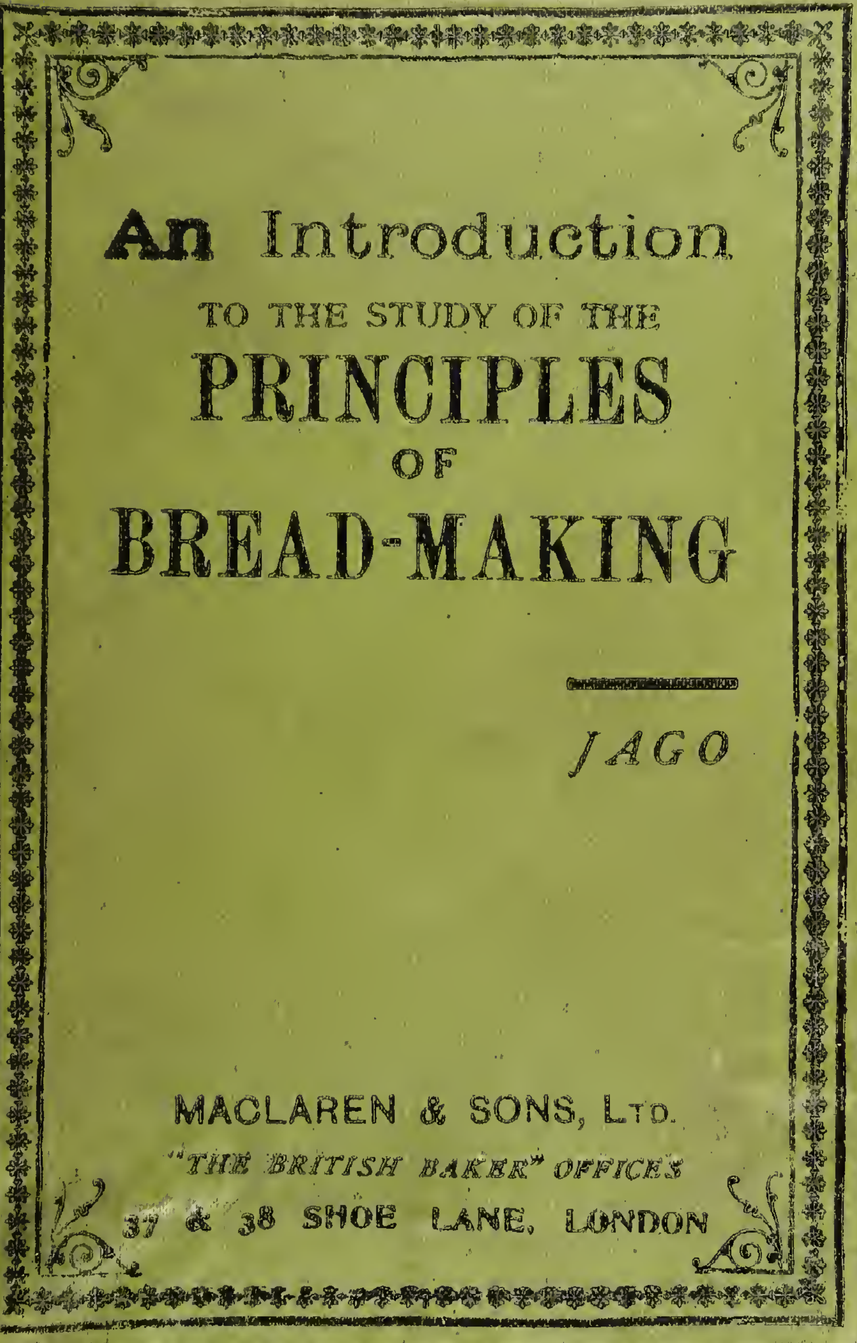


An Introduction
TO THE STUDY OF THE
PRINCIPLES
OF
BREAD-MAKING

JAGO

MACLAREN & SONS, LTD.
"THE BRITISH BAKER" OFFICES
37 & 38 SHOE LANE, LONDON

THE *FIRST* PRINCIPLE
OF BREAD-MAKING

IS
T.

It
yea
yea
fin
ov
tes
wo
tha
an

ur
est
he
ed
le
in
er
st,
al.

LIBRARY OF THE
NEW YORK STATE COLLEGE
OF HOME ECONOMICS
CORNELL UNIVERSITY
ITHACA, NEW YORK

THE UNITED YEAST Co., Ltd.,
Head Office:—**80, MILLER ST., MANCHESTER,**
AND IN OVER 150 CITIES & TOWNS THROUGHOUT THE BRITISH ISLES.

SHOULD be alert to the advantages of a "Bermaline" Agency. "Bermaline" in your window display will assuredly bring customers. Your trade will increase—and so will your profits.

Terms and Particulars from—

MONTGOMERIE & Co., Ltd.,
IBROX, GLASGOW.

"BERMALINE"
BREAD

We are the ORIGINAL Suppliers of

FRESH LIQUID WHOLE EGGS

DRIED EGG WHITES

PRIME LIQUID HEN YOLKS

Quality Guaranteed.

STILL THE BEST FOR BAKERS & CONFECTIONERS.

Cream Powders.
Sweetened Condensed Milk (in casks)
Separated Milk Powder.
Marzipan.
Almonds—Ground, Nibs, Flakes.
Almond Substitutes.
Ice Cream Powders.
Bakers' Sundries.

Carriage Paid to any Address in the United Kingdom.

H. D. HARDIE & Co.,

Head Office and Works—
11/27 BISHOP STREET, ANDERSTON, GLASGOW.
Telegraphic Address:—"Azote, Glasgow."
Telephones:—Central 9982, 9983, 9984.

London Office—
174 HIGH STREET, ACTON, W.3.
Tel. Address:—Stiracto, 'Phone, London.'
Telephone:—Chiswick 400.

Belfast Office—**45, ANN STREET, BELFAST.**

AN INTRODUCTION

TO THE STUDY OF THE

Principles of Bread-making.

BY

WILLIAM JAGO, F.C.S., F.I.C.,

Examiner and Lecturer on Bread-making to the City and Guilds of London Institute
the Advancement of Technical Education.

Author of "Inorganic Chemistry, Theoretical and Practical,"
"The Chemistry of Wheat, Flour, and Bread; and Technology of Bread-making,"
&c.

OFFICES OF "THE BRITISH BAKER,"
37 & 38, SHOE LANE, LONDON, E C.

CONTENTS.

Lc 14605

CHAPTER. PAGE.

I. CHEMICAL INTRODUCTION 5

II. HEAT 21

III. CONSTITUENTS OF WHEAT AND FLOUR ... 48

IV. FERMENTATION 65

V. PRACTICAL BREAD-MAKING OPERATIONS ... 76

VI. YEAST AND FLOUR TESTING 115

Cornell University Library
TX 769.J24A
An introduction to the study of the prin
3 1924 003 582 826
mann, vaul

PRINCIPLES OF BREAD-MAKING.

CHEMICAL INTRODUCTION.

1. Introductory.—The object of this little work is to state, for the benefit especially of the working baker, what may be called the Elementary Principles of the Science of Bread-making, in as simple and clear a form as possible. The reader must not be alarmed because at the very outset he is told that this is to be a scientific work, for the word "science" after all, only means *knowledge*, or, putting it a little more fully, *knowledge arranged systematically*. The knowledge that that the writer will endeavour to impart is

1. That of the nature of the substances used in bread-making.
2. That of the changes which these substances undergo during this process.
3. That of how to guide and direct these changes so as to produce the best results.

In order to understand these, careful attention is necessary, and if the student will only give this right through from the commencement of the book, it is hoped that everything will be made quite clear to him.

The nature of flour and other substances cannot be explained without some knowledge of chemistry. We shall also have to know something of the laws and properties of heat, on which so many bread-making changes depend. We will, therefore, at first try to give some explanation of both these.

2. Meaning of Chemistry.—The actual meaning of this word is very simple: **Chemistry deals with the composition of substances, and with the changes in composition which occur when different substances are placed together, or are acted on by heat and other natural forces.**

3. Elements.—In order to find out of what substances are composed the chemist analyses them, or, as it is sometimes called, "subjects them to analysis." This operation consists in separating the various ingredients from each other. But analysis is not performed by the chemist alone; the baker also makes analyses as part of his everyday work. For example, he takes currants as they come to him, and, by washing them, separates out on the one hand clean currants, and on the other stones and stalks with which they were mixed. The operation is just as much analysis as many performed by the chemist. But the baker's analysis of dirty currants is complete when he has separated the clean fruit from the foreign impurities. If he should weigh his currants first, and then afterwards weigh his clean fruit, and the stones and stalks, his analysis would not only have enabled him to separate the substances, but also would have told him the *quantity* of each substance present. He would, in fact, have performed a "*quantitative analysis.*" Of course this fruit-cleaning operation is a very simple one: substances which were mixed have been separated. But suppose you take the inner pulp of the fruit, or the stones which have been removed, they will possibly seem on examination to be quite uniform in appearance throughout. The chemist, however, will want to find out whether he can separate the fruit-pulp and the stones each again into separate ingredients, and accordingly he makes a number of experiments on these substances. Not only stones and fruit, but every other substance the chemist can obtain for examination has been thus tested. As a result, every known body, except about seventy substances, have been found capable of being separated into two or more distinct ingredients. These seventy substances (or thereabouts) are termed elements. It will now be quite plain what the chemist means when he says that **an Element is a substance which has never been separated into two or more dissimilar substances.**

A good many of these elements are very familar bodies; for instance, among them are included iron, copper, gold, and all the metals. There are, beside, some elements which are not metallic in their nature, such as sulphur (often called brimstone), carbon (of which charcoal is an impure form), and other substances. On the other hand, some elements are exceedingly rare, and to obtain a few grains of them only, tons of material have been worked over. These very scarce elements are of very little importance to the baker.

The following is a list of those elements more intimately connected with substances used in baking:

TABLE OF ELEMENTS.

NAME.	SYMBOL.	ATOMIC WEIGHT.
Aluminium	Al	27
Barium	Ba	137
Boron	B	11
BROMINE	Br	80
Calcium	Ca	40
CARBON	C	12
CHLORINE	Cl	35.5
Copper	Cu	63
HYDROGEN	H	1
IODINE	I	127
Iron (Ferrum)	Fe	56
Lead (Plumbum)	Pb	206
Magnesium	Mg	24
Mercury (Hydrargyrum)	Hg	200
NITROGEN	N	14
OXYGEN	O	16
PHOSPHORUS	P	31
Potassium (Kalium)	K	39
Silver (Argentum)	Ag	108
SILICON	Si	28
Sodium (Natrium)	Na	23
SULPHUR	S	32

Those elements printed in the above list in small capitals are not metals, and are called non-metals, or sometimes metalloids. The remainder are all metals.

The columns headed "Symbol" and "Atomic Weight" will be explained a little later on.

4. Mixtures and Compounds.—Although the number of elements is not large, yet by their mixture and combination in different proportions and ways, they produce all the varied substances we find in earth, air and sea.

Everyone understands what is meant by the term mixture. If we have two kinds of flour, the one very strong and dark in colour, the other weak but of a bloomy white, they may be mixed in any proportion we like. If half and half are taken, the mixture will be half-way in colour between the two, and the same with regard to strength. If, on the other hand, there is more of one than the other, whichever is present in greatest quantity will govern the properties of the mixture. But, after all, the flours are nothing more than mixed ; no combination or actual act of union has occurred. The fine dusty particles are simply lying side by side. Suppose, in addition to the two flours being the one strong and the other weak, that one of them is very "high ground" and granular, and the other "low ground" and very fine indeed. Then in this case they might once more be almost completely separated by sifting through silk ; just, in fact, as the miller dresses flour during the various operations of milling. Now, all this is an illustration of what the chemist means by a mixture, and he accordingly says that **a Mixture is produced by the mere blending of two or more bodies, in any proportion without union.** Each substance present retains its own properties, and the properties of the mixture are a mean, or average, of those of the various ingredients.

In addition to substances being mixed, they may *combine* with each other, in which case the resultant body usually differs very considerably from those which by their union have resulted in its production. An experiment will make this far clearer than pages of simple description. Procure some "flowers of sulphur" from a chemist's, and also some copper filings. If these last cannot be obtained, take some fine copper wire and cut it into little pieces about ⅛in. in length. Everyone knows the properties of both these bodies. The sulphur is a lemon-yellow body, which burns with a pale blue flame, and produces a gas which has a very strong smell. The copper is a tough, reddish -coloured metal. Take about equal quantities, and mix them thoroughly. The little fragments of copper can be seen clearly in the mixture, so can the sulphur. Here, then, is a "mixture," as we have just before defined it, and it will be found to answer all the conditions stated. The two can be very easily separated from each other. Next put this mixture in an iron ladle or spoon, and place it on a clear fire. The sulphur melts almost immediately, and then the little bits of copper become red hot and a glow passes over the mixture. Let it now cool, and then examine ; neither sulphur nor copper can be distinguished, but in their place remains a blue-black mass. Test this substance, it is very brittle ; put a little in the fire, it does not burn ; it no longer possesses the properties of either copper or sulphur, but is a *compound* of these bodies called sulphide of copper. If this sulphide be carefully analysed, it is found to contain always unchanging proportions of both ingredients. This is always the case with compounds. The chemist accordingly says that **a Compound is a body produced by the union of two or more elements in definite proportions, and consequently is a substance which can be separated into two or more unlike bodies.** Compounds usually differ in appearance and properties from the elements of which they are composed.

In this one instance a fact has been explained by means of experiment. The size of this little work, will, however prevent this being repeated in the case of the ordinary laws of chemistry, especially as there is an abundance of other books which treat entirely of this subject. Among these is *Inorganic Chemistry*, written by the author of this work, and published by Longmans & Co. The student is strongly recommended to attend, if possible, a bread-making class held in connection with the City and Guilds of London Institute for the Advancement of Technical Education, or science classes in Chemistry and Heat under the Science and Art Department. In either he would see these elementary facts of chemistry and heat made plain by experiment.

5. Matter and Force ; their Indestructibility.—The word *matter* is a most convenient one to the chemist ; it means anything which has weight. Thus, if a lump of iron is given you by any person, and you put it in your pocket, you are sensible of having received it, because you feel it heavy. It is a piece of matter because it possesses weight. But if some person gives you a blow, accidental or otherwise, you know you have received it because of its effects ; but you can neither weigh it nor put it in your pocket—it is not matter. Still it is something ; for if it were nothing it could produce no effect. It is a common expression to say that a man is *struck with great force*. This something which is not matter is called **force. Matter, then, is anything which possesses weight, and exists in three distinct forms—namely, solids, as iron ; liquids, as water ; and gases, as air.** Gases, it must be remembered, possess weight, just as liquids and solids do. A bottle full of air weighs more than the same bottle absolutely empty.

In a general way, we all have some idea in our mind of force ; but as it is nothing we can see, our ideas are apt to be rather hazy. We often say that the wind blows with great force, although we never see it. How, then, do we know of the force? By its effects. A tree or house may be blown down, or, as is more constantly occurring, a ship is blown rapidly by it over the sea. Now, a ship is matter, and when blown along, is *matter in motion.* It has been found most convenient to define force by the effects it produces, and so we say, **Force is that which is capable of setting matter in motion.**

Whatever you do, you cannot destroy matter. If you take a candle and burn it, it has disappeared, and you may think is destroyed; but it is not so. The candle, in burning, has simply been changed into certain invisible gases which are present in the air. It is quite possible to collect all these and weigh them; which this is done, the candle is found to be completely accounted for. Neither can you destroy force. Take a hammer, and hit away with it at a piece of iron rod until you are tired. You have used up a lot of your force, which apparently has been wasted; but examine the iron rod, and you will find it to be *hot.* The muscular force of the arm has been converted into another form of force called heat. However force may apparently disappear, "it will turn up again some day." It is simply a fact that most of the force we now use for practical purposes in everyday life has lain, as it were, asleep within the crust of the earth for hundreds of thousands of years, to be once more set at liberty in active form through the agency of man. **Never forget, then, that both matter and force are indestructible.**

6. Atoms and Molecules.—In the experiment with sulphur that element is in a very fine powder; but if looked at under a microscope the powder will appear to be very coarse—each grain would seem a lump of considerable size which could be easily broken down much finer. Suppose this were done, we might still imagine that by breaking each particle in two a yet finer particle could be produced. It used to be a favourite speculation as to whether this dividing and dividing could be carried on without end, or whether at last a limit would be reached beyond which further subdivision was impossible. Scientific thought and research now lead us to the opinion that there is such a limit, and that all elements are composed of particles which are incapable of further subdivision. These particles are called *atoms*, a word meaning "which cannot be cut." When two elements combine as did the sulphur and the copper in our experiment, the chemist believes that they combine an atom of copper with an atom of sulphur. The particle of sulphide of copper formed by the union of these two atoms he calls a *molecule*. These molecules must be exceedingly small, yet their actual size within certain limits has been calculated. Let us imagine a drop of water to be taken and enlarged until it was the size of the earth, the enlargement being caused by the growth of each molecule of water present ; then the molecules themselves would be smaller than cricket balls and larger than peas.

It will now be understood that all compounds consist of molecules. Thus, if the drop of water to which reference has been made was subdivided, the smaller particles would still consist of water. At last, however, supposing we could go on far enough, a limit would be reached ; for a particle would be obtained that could not be split up into two particles of water. This particle would be a *molecule* of water. If it were split any further it would be into, *not water,* but into the *atoms* of oxygen and hydrogen of which water is composed. There is another interesting point about these molecules ; for not only are compounds built up of molecules,but also so are the elements. Thus, if we take some hydrogen gas, we find that the atoms present have united in pairs, each of those pairs being a *molecule* of hydrogen gas. Let us see if once more we can sum up our knowledge in the form of a definition. The chemist states that **an Atom is the smallest particle of an element which enters into or is expelled from a chemical compound.** You will notice that this definition is not quite so extensive as our previous explanation. The chemist, as such, does not trouble himself any further about these atoms than in their relation to the chemical behaviour of elements and compounds.

Let us next try to express the meaning of molecule. **A molecule is the smallest possible particle of a substance, whether elementary or compound, that can exist alone.** Molecules cannot be subdivided except by separation into their constituent atoms. This, of course, means the decomposition of compounds. Thus it would mean in the case of water its separation into oxygen and hydrogen gases.

7. Symbols and Formulæ.—In the table of elements already given it will be noticed that one column is headed

"Symbols." These are convenient shorter names for the elements, and when possible consist of their first letter; thus, carbon has C for its symbol, and as other elements as chlorine also commence with C, chlorine has chosen for it the symbol Cl. The symbols are usually selected from the *Latin* names of the elements; these are, when necessary to explain the symbol, given in brackets. But the chemist makes another, and to him still more valuable use of the symbol; it is taken as a measure of quantity—thus, if he writes C, he not only means that he is dealing with carbon, but that he is dealing with *one atom* of carbon. Now, when it comes to compounds they also have a kind of symbol of their own, only the symbol of a compound is called its *formula*. Our first compound was sulphide of copper. This, we know, is composed of sulphur and copper; its formula is CuS. This not only tells us that sulphide of copper is composed of copper and sulphur, but also that its molecule contains *one atom* each of copper sulphur. In the case of another body, water, the formula is H_2O; from this we know that the molecule of water consists of *two* atoms of hydrogen to one of oxygen.

8. Chemical Equations.—The chemist makes a still further use of his symbols and formulæ; for by means of them he not only shows the composition of bodies, but also explains chemical changes. For instance, to mention again our now very familiar experiment of causing copper and sulphur to combine, the chemist thus states this chemical action:

$$\underset{\text{Copper.}}{Cu} \quad + \quad \underset{\text{Sulphur.}}{S} \quad = \quad \underset{\text{Sulphide of Copper.}}{CuS.}$$

This means that one atom of copper, together with one atom of sulphur, have yielded one molecule of sulphide of copper, consisting of one atom each of sulphur and copper. This is called a chemical equation. Let us try another a little more complicated:

$$\underset{\text{Hydrogen.}}{2H_2} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad + \quad \underset{\text{Water.}}{2H_2O}$$

This means that two molecules of hydrogen, each consisting of two atoms, together with one molecule of oxygen consisting of two atoms, have combined to produce two molecules of water, each containing two atoms of hydrogen and one atom of oxygen. It will be noticed that the large figure before the formula means that number of molecules, that is H_2O means two of the whole group which follow it. The little figures slightly below the line simply refer to the symbol immediately before them.

Symbols and equations are frequently the bugbear of the chemical student, but I want you to see how very simple they really are. You will find that if you once really understand them, it will make your future progress wonderfully easier. Things that would require pages of explanation without them and even then would be very difficult to grasp, are rendered clear at a glance by the use of equations.

9. Atomic and Molecular Weights.—With regard to atoms, enough has been already said to show that the chemist has acquired a good deal of knowledge concerning them ; but one thing yet remains to be told ; their weights, compared with each other, have been most carefully determined. It has been found that the atom of hydrogen weighs less than any other atom ; it has been decided to consider the atom of hydrogen as weighing 1 ; the weight of other atoms is then given in terms of that of hydrogen. These atomic weights are given in the same table as the symbols of the elements. Thus, the atomic weight of carbon is given as 12 ; this means that if one had a sufficiently delicate balance, and placed an atom of carbon on the one pan, 12 atoms of hydrogen would have to be placed on the other to balance it. In other words, the atom of carbon is 12 times as heavy as that of hydrogen. It may perhaps save some misconception to mention that atoms are far too small to be actually weighed direct as above suggested. Their weight is obtained by indirect means, these are explained in the larger treatises on chemistry.

By reference to the table it is seen that the atomic weight of sulphur is 32, and that of copper 63 ; as the molecule of sulphide of copper consists of an atom of each of these elements, its weight must be 63 and 32 added together—that is, 95. The molecule weight of a compound is the sum of the weights of the atoms present. Let us repeat one of our equations, and place the atomic and molecule weights underneath :

$$\begin{array}{c} 2H_2 \\ \underbrace{2 \times (1 \times 2)} \\ \underbrace{2 \times 2} \\ 4 \end{array} + \begin{array}{c} O_2 \\ \underbrace{16 \times 2} \\ 32 \\ \end{array} = \begin{array}{c} 2H_2O \\ \underbrace{2 \times (1 \times 2) + 16} \\ \underbrace{2 \times 18} \\ 36 \end{array}$$

Taking first the hydrogen, we have 2 atoms in the molecule, each weighing 1, they together make 2 ; and as there are 2 molecules, they together make 4. The molecule of oxygen weighs 32, being twice 16. The molecule of water contains 2 atoms of hydrogen weighing 2, and 1 atom of oxygen weighing 16 ; these together weigh 18. Then, as there are two molecules of water, they together weigh 36. Now, this is all very simple, but still it is of very great importance. We know from this equation that 4 parts by weight of hydrogen combine with 32 parts by weight of oxygen to form 36 parts by weight of water. Now, whatever these 4 parts are, whether they are ounces or pounds or tons, 4 ozs. of hydrogen will combine with 32 ozs. of oxygen, 4 lbs. with 32 lbs., and so on. In this case we have a quantity of oxygen 8 times the weight of that of hydrogen ; and always hydrogen combines with 8 times its weight of oxygen and forms 9 times its weight of water. **In every Chemical Equation, the atomic and molecular weights, placed under the symbols and formulæ, give the proportions by weight in which the different substances, taking part in the chemical action referred to have been present.** The great use of this will be seen in some of the calculations that will have afterwards to be explained.

10. Principal Elements and Compounds.—Having now got an idea of some of the most important principles of chemistry, it will be advisable to give here a short description of certain elements and compounds which have a very close connection with our subject of bread-making. These descriptions must of necessity be very brief and incomplete. It is hoped that they will encourage the reader to acquire more extended information from larger treatises.

11. Hydrogen, H_2.—This element is gas, and is the lightest substance known. It has neither colour, smell, nor taste, and is not poisonous. Hydrogen is inflammable ; that is to say, it takes fire when a light is placed to it. It does not however, give a bright light like coal gas, but burns with a blue flame, so pale that in daylight it can scarcely be seen.

12. Oxygen, O_2.—Like hydrogen, this element is a gas, and is also without colour, smell, or taste. But oxygen is very different in one particular, inasmuch as it is not inflammable. If you put a light in some oxygen, the oxygen does not take fire, but the light itself burns very much more brightly. The leading property of oxygen is that it supports the combustion, or the burning of inflammable bodies, such as hydrogen, coal gas, coal, wood, and all substances used for fuel. The reason why these things burn in air is that air contains a large quantity of oxygen ; but the oxygen of air is mixed with another gas which does not support combustion. As a consequence, inflammable bodies do not burn in air anything like so vigorously as they do in oxygen gas in its pure state. Coupled with its power of supporting combustion is the property which oxygen alone possesses of supporting the act of respiration or breathing. Oxygen is slightly soluble in water ; 100 volumes of water at ordinary temperatures dissolve three volumes of oxygen gas.

13. Water, H_2O.—Water is a compound of 2 atoms of hydrogen with 1 atom of oxygen. At ordinary temperatures it is a liquid, but with cold it freezes, and thus forms the solid ice ; on being heated it boils, and is changed into an invisible gas called steam. On cooling, steam first condenses into a cloud of small particles of water, and thus becomes visible ; these, by joining together, form larger drops, which may be collected again, when desired, in a suitable vessel. Water is neither inflammable, nor is it a supporter of combustion. One of the most important properties of water is that it dissolves more or less of almost all other substances. Thus, gases, such as oxygen, are dissolved by it; some in very small quantities, others in very large volumes. The gas known as ammonia is dissolved by water to the extent of about 700 volumes of ammonia in 1 volume of water. Many liquids mix readily with water in any proportion, as for example, sulphuric acid ; others, such as oil, do not mix with water, and if they and water be shaken together, they almost immediately separate into two layers. Everyday life furnishes innumerable instances of solids dissolving in water, as, for example, salt and sugar. In nearly every instance hot water dissolves more of any solid substance than does cold; but salt is an exception to this rule, being soluble to as great an extent in cold as in hot water. Owing to this property of so readily dissolving other bodies, water is never found in a state of purity in nature. When required pure for chemical purposes, the steam from boiling water is condensed and collected; all solid impurities remain in the vessel in which the water is boiled.

14. Nitrogen, N_2.—This element is a gas and constitutes about four-fifths of the atmosphere. Nitrogen in its uncombined state is a neutral and very inactive body. It has neither colour, taste nor smell; it is not inflammable, and neither supports combustion nor respiration, but on the other hand, has no actual poisonous properties. It forms, however, notwithstanding its own lack of very positive qualities, a very active and important series of chemical compounds.

15. The Atmosphere.—Ordinary air, or the atmosphere, consists principally of nitrogen and oxygen, and is a mixture of these gases in the proportion of about 4 parts of nitrogen to 1 part of oxygen. The nitrogen and oxygen are not united in any way. In addition to these two gases there are smaller quantities of other substances present. The following table shows the proportion of each of these in 10,000 parts of air:

Oxygen, O_2	2,061
Nitrogen, N_2	7,795
Carbon dioxide, CO	4
Water vapour, H_2O	140
	10,000

Beside these, there are small traces of nitric acid, ammonia, and other bodies. It has been already explained that oxygen supports combustion much more vigorously than air. Pure oxygen is so energetic in its action that breathing it is practically impossible. Just as whisky, or other spirit, is too strong to be drunk in the pure state, and has to be diluted down with water, so oxygen is in the atmosphere diluted down with nitrogen until the mixture is just of that strength best fitted for the sustenance of life.

16. Carbon, C.—This element is known only in the solid state, and is remarkable for existing in three distinct forms as different from each other as can well be imagined. One of these is a diamond, another is a graphite, or black-lead, of which pencils are made, and a third kind is charcoal, such as is obtained from wood and other sources. The presence of carbon in wood, flour, meat, bones, and almost every other animal and vegetable substance, is easily shown. If any of these bodies be heated to redness in some vessel which keeps them out of contact with the air, a black mass remains; this is charcoal, which is simply the third variety of carbon in an impure form. Whenever, through the use of a too-hot oven, bread is burned, the same chemical change has occurred. Carbon in all its forms is inflammable, and in burning produces a gas termed carbon dioxide, CO_2. If the supply of air is deficient more or less of another gas, carbon monoxide, CO, is formed. These two changes may be represented as follows:

$$\begin{array}{ccccccc} C & + & O_2 & = & C_2O. \\ \text{Carbon.} & & \text{Oxygen.} & & \text{Carbon Dioxide.} \\ 2C & + & O_2 & = & 2CO. \\ \text{Carbon.} & & \text{Oxygen.} & & \text{Carbon Monoxide.} \end{array}$$

Among its other properties charcoal is characterised by the property of removing the colour from any coloured liquids, and also by its power of absorbing and rendering harmless many evil-smelling gases.

17. Carbon Dioxide.—This is a most important gas to the baker. It is produced, as above mentioned, by the burning of carbon, and as carbon is the chief constituent of all kinds of fuel, it is also largely produced by the burning of such substances. All animals in breathing consume oxygen and breathe out carbon dioxide from their lungs or other breathing apparatus. Carbon dioxide is somewhat sweetish in taste, and has a brisk, pungent smell; it is poisonous to breathe, but may be taken into the stomach without injury. This gas does not burn, neither does it support combustion; it is about half as heavy again as air. Carbon dioxide is soluble in water; a pint of water at ordinary temperatures dissolves about a pint of the gas. The quantity dissolved can be much increased by pumping the gas into water under pressure. Carbon dioxide is distinguished by the property of turning lime-water milky.

18. Carbon Monoxide.—This gas is exceedingly poisonous, and is formed whenever carbon burns with a limited supply of air. Thus, in a furnace burning coke, the air as it passes upwards is deprived of most of its oxygen in the lower part of the fire ; in the more central layers the carbon is burning in a deficiency of oxygen, and consequently only forms the monoxide. The monoxide is itself inflammable, and may be seen burning at the top of the fire when clear with a pale blue flame. It is well in all furnaces burning coke to allow air to enter over the top of the fire in order that this carbon monoxide may burn, otherwise it escapes from the chimney unused. For this reason it is advantageous to have furnace doors always slightly open.

19. Combustion.—This term has been frequently used, and everyone understands combustion to be another name for the act of burning. Now, in practically every instance where two substances combine, heat is evolved during the process. Thus, when hydrogen burns it *combines* with oxygen to form water, and produces great heat ; so, too, when carbon burns it *combines* with oxygen to form carbon dioxide, and likewise evolves heat. **Whenever the heat caused by chemical union is sufficiently intense to raise the resultant substances to a temperature at which they emit light, the act of union is termed "combustion."** All ordinary kinds of fuel are essentially composed of hydrogen and carbon, and yield in burning water and carbon dioxide in proportions depending on the relative amounts of the elements hydrogen and carbon in the original fuel. This is one of the chemical facts which can easily be tested by experiment. Place a kettle of cold water over a jet of burning coal gas ; notice that the bottom becomes wet. Observe the same thing with a candle. Some lime-water will be required for the next experiment. Lime-water may be prepared by shaking up a lump of quicklime, say the size of an egg, with a gallon of water in a jar. The lime should be allowed to settle, and after about twelve hours the clear liquid on the top carefully poured off without disturbing the sediment. This clear liquid is "lime-water," and is simply a solution of lime in water. Take an ordinary pickle-bottle (of course quite clean), and pour about an eggcupful of the lime-water into it. Shake it up thoroughly. Notice that the lime-water acquires a faint bluish tint through becoming slightly turbid.

Next fix a candle to a piece of wire, light it, and dip it while still lighted into the bottle. In a few seconds the candle burns smoky, and then goes out. Pull it out of the bottle, and again shake up the lime-water. It now turns quite milky. This is due to the carbon dioxide which has been formed by the burning of the candle.

In addition to the rapid combination of carbon and hydrogen with oxygen, in such a way as to produce heat and light in the act of burning, the compounds of these elements with each other also under certain circumstances combine slowly with oxygen. This takes place for instance in the slow decay of wood. Not only is heat evolved during the act of rapid combustion, but also during this slow combination; in consequence, such combination with oxygen is often termed "slow combustion." In connection with this, it should be mentioned that the same quantity of inflammable material gives out precisely the same quantity of heat, whether it is burned quickly or slowly. Thus, if a piece of wood is burned in a furnace it produces a certain quantity of heat; if allowed to combine with oxygen to the same extent, by a process of slow decay exactly the same amount of heat is generated. In the one case the whole of the heat is evolved during a few minutes; in the other its evolution may be spread over years.

20. Respiration.—Very similar, indeed, is respiration, or the act of breathing, to combustion. Air is taken into the lungs, and its oxygen combines with the carbon and hydrogen of the blood; the air driven out of the lungs during breathing is charged with moisture and carbon dioxide gas. Breathe for a few seconds through a piece of tube into lime-water: the liquid becomes milky in just the same way as when shaken up with the air in which a candle had been burned. Animals in breathing, use oxygen from the air, and by slow combustion with carbon and hydrogen from the compounds of the blood, evolve carbon dioxide and water from the lungs. In this way the animal heat is kept up. There are certain peculiar instances of breathing in which the oxygen is obtained, not from air, but by first decomposing bodies rich in oxygen, and using a portion of it for the carrying on of this act. This form of breathing will be dealt with at length in a future chapter.

21. Acids, Bases, and Salts.—A very large number of chemical compounds belong to one of these three classes. Let us see what the terms mean. First, everyone is acquainted with the term acid, because it is being continually applied to things which are sour. All acids, under the modern definition of that term, contain hydrogen in such a form that that element is readily displaced from the acid under favourable circumstances. The following is an exact definition of an acid: **An acid is a body which contains hydrogen, which hydrogen may be replaced by a metal (or group of elements equivalent to a metal) when the metal is presented to the acid in the form of an oxide or hydrate.** The acids are very active bodies, and are characterised by the property of changing the vegetable-blue colour known as litmus to red.

The definition of a base is easily led up to from that of an acid ; the bases are, in fact, the compounds of the metals referred to in the definition of an acid as replacing the hydrogen. **A Base,** therefore, **is a compound, usually an oxide or hydrate, of a metal (or group of elements) equivalent to a metal, which metal (or group of elements) is capable of replacing the hydrogen of an acid when the two are placed in contact.** Most compounds of metals with oxygen are bases. Some soluble and very energetic bases are called "alkalies ;" the most important of these are sodium hydrate, $NaHO$, and potassium hydrate, KHO. The alkalies restore the blue colour to reddened litmus.

The definition of a salt follows naturally from the two already explained. **When an acid and base react on each other, the body, produced by the replacement of the hydrogen of the acid by the metal of the base, is termed a salt.** Most salts have no action on litmus, that is, they do not affect the colour, whether red or blue. The relation of acid, base, and salt to each other is well shown in the following equation :

$$HCl + NaHO = NaCl + H_2O$$

Hydrochloric Acid.	Sodium Hydrate.	Sodium Chloride.	Water.
Acid.	Base.	Salt.	

22. Ammonia, NH_3.—This is a gas known by its characteristic smell, which is that produced by ammonium carbonate the "volatile" of the baker. The great source in nature of ammonia is the decomposition of animal and vegetable substances containing nitrogen. Ammonia is very soluble in water; the solution is alkaline, and neutralises the strongest acids, forming ammonium salts.

23. Sulphur, S_2.—This element is a brittle yellow solid with little or no smell. It is also known under the name of brimstone. Sulphur melts readily, and burns with a formation of sulphur dioxide, SO_2. Sulphur is found, not only in many mineral substances, but also as a constituent of a number of bodies of animal and vegetable origin.

24. Sulphuretted Hydrogen, SH_2.—This is a colourless gas, possessing the unpleasant odour of rotten eggs. The gas is soluble in water, and is inflammable, producing water, H_2O, and sulphur dioxide, SO_2. Sulphuretted hydrogen is produced in nature during the putrefaction (going rotten) of animal and vegetable bodies containing sulphur. Rotten eggs are an instance.

25. Sulphur Dioxide, SO_2.—This is a gas with a peculiar suffocating smell, produced by the burning of sulphur in air or oxygen.

26. Phosphorus, P_4, and Phosphates.—The element phosphorus is principally important in connection with bread making because of its compounds. Phosphorus forms an acid H_3PO_4. This in its turn produces salts called phosphates. Of these, calcium phosphate, $Ca_3P_2O_8$, and potassium phosphate, K_3PO_4, are distinguished by being highly valuable constituents of wheat and other substances used as food. A supply of these bodies is necessary, because bones are largely composed of phosphates; and hence a food in which phosphates are absent is incapable of adequately supporting the human body.

27. Summary.—In this chapter the attempt is made to explain to the reader in a very simple manner the most elementary facts of chemistry. Without understanding these, it would be impossible to grasp what follows of the chemistry of flour and the changes of bread-making. It may be that on first reading everything will not seem quite clear. The best course is then to read the whole over, and more carefully. The student must not expect to master the whole in one reading.

CHAPTER II.

HEAT.

28. The Property of Being Hot.—Let us take a piece of iron, particularly on a winter's day. We find the piece of iron decidedly cold to the touch. Let this piece of iron be placed for a few seconds in the fire, and then touched once more: there is a pleasant sensation of warmth. With further heating the iron gets too hot to touch without burning the skin. Further heat makes it red-hot. In this stage, if taken in a dark room, the iron gives out light. Now, as a result of being placed in the fire, the iron has become hot, or has acquired heat. On placing the hand near the hot piece of iron, warmth is felt to be proceeding from it, and the iron itself at the same time gradually grows cold. The addition of heat will not, in the first place, have caused the iron to increase in weight neither, during the act of cooling, will the iron have lost in weight. We are consequently forced to the conclusion that heat is something which does not possess weight; that, in fact, according to our definition, it is not matter. From its other properties we know heat to belong to what are called the "natural forces."

29. Sensation of Warmth.—We cannot measure heat in the same way as we measure a piece of iron or flour, by weighing them, but must judge of its presence or absence by testing for the effects heat can produce. The most familiar of these is the sensation of warmth. Fill one basin with cold water and another with warm water, and place a hand in each: they are at once distinguished by one *feeling* cold and the other warm. Here is a very simple test, and an extensively used one: Bakers commonly judge the water which they use for bread-making purposes by how it feels to the hand, and add either hot or cold water according to their judgment. At the best this is but a rough method of testing, even if the hand itself were always in the same state. But as one's hand may be either hot or cold to start with the sensation to the hand of warmth is liable to be very misleading. This may be illustrated in the following manner. Take three basins, fill one with cold water, another with water as hot as can be borne, and the third with a mixture of the two in about equal quantities. Place one hand in the hot and another in the cold water; then in about a minute take the hand from the hot water and place it in the third basin, in which the water is lukewarm. This water feels decidedly cold to the hand. Next, plunge into the lukewarm water the hand which has been immersed in cold water: the lukewarm water feels comparatively hot to this hand. In this test we find that a basin of lukewarm water may convey the impression of heat or cold according to the previous treatment of the hand by which it is tested. The sensation of warmth, then, must only be taken as a very rough measure of heat. The question may very easily occur to us here, Why should warm water impart the sensation of warmth to the hand? In a general way this may be answered by stating that **whenever two bodies are placed in contact with each other, one of which is hotter than the other, the hotter body of the two gives up heat to the colder until the both are equally hot.**

30. Temperature.—It will be noticed that in judging of how hot a body is by the hand, we are guided by the capactiy it has to impart heat to the hand when in contact with it. Thus, if there are two vessels of water, the one slightly warmer than the other, the one which makes the hand feel the hotter is decided on as being the warmer of the two. Naturally the hand feels the hotter in that lot of water which is most readily imparting heat to it. Now, what I want to do here is to impress the fact that how hot a body is is simply judged by the power it has of imparting its heat to other bodies. If a substance cannot yield heat to our bodies when placed in contact, we say that it is cold, while if it does yield heat we say that is is warm or hot. It doesn't matter how much heat the body actually contains, if it will not yield any it is said to be cold. Now this fact must be quite grasped. We come next to giving a better name to "how hot a body is," and this name is "temperature." Let us define this term: **Temperature is the measure of "how hot a body is," and is further explained as the measure of the heat condition of a body considered with reference to its power of communicating heat to other bodies.** When bodies are equally hot they are said to be at the same temperature.

31. Measurement of Temperature.—We come next to methods of measuring temperature, and as the sensation of warmth is not a trustworthy indication of temperature, we must select some other effect produced by heat. The best of these for our present purpose is the alteration of the size of bodies; for **under the influence of heat, all bodies, with very low exceptions, whether solids, liquids, or gases, expand and again contract as they become colder.** This property is very easily illustrated: Take a clear glass bottle or flask, and fill it to within a $\frac{1}{2}$in. from the top of the neck with cold water. Stand the bottle in a saucepan also containing cold water, and place it over the fire. As the water gets hot it will be seen to rise in the bottle until it at last overflows. When nearly boiling take it (the bottle) out and allow it to cool: the water will shrink considerably in bulk. The reason for the use of the saucepan in this experiment is that the glass bottle would crack if placed direct on a fire. This bottle full of water gives us a very rough method of measuring temperature by the expansion of the water.

32. The Thermometer.—By an improvement on the water bottle we come to the instrument well known as a thermometer. This word really means a heat, or rather temperature, measurer. Several forms of thermometer are shown in Figure 1.

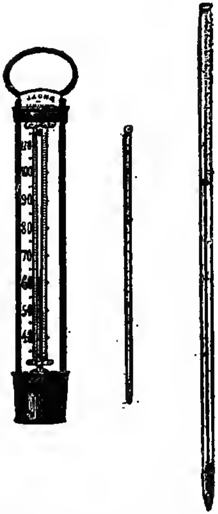


FIG. 1.—THERMOMETERS.

a, Thermometer with copper back and cup for dipping in liquids; *b*, chemical thermometer for pushing through corks, graduated on the stem; *c*, similar thermometer with long stem for taking the temperature of dough.

In making a thermometer the instrument-maker takes a piece of glass tubing with a very fine bore ; not large enough. in fact, to admit a fine pin. He blows a bulb on the end of this and fills his bulb and part of the stem with the metal known as quicksilver or mercury. The air remaining in the upper part of the stem is next driven out, and the top sealed by melting the glass of the tube. The bulb and stem answer the same purpose as the bottle, only the neck is very long and narrow. Mercury is chosen in preference to water because it expands very regularly, and also because it requires a very low temperature to freeze it, and a very high one to make it boil. Now, with such an instrument as this would be, without any markings of any kind whatever, a number of very important facts may be learned. Every student who really wishes to gain practical knowledge of his subject ought to possess at least a thermometer, and these instruments can now be procured very cheaply. In large towns there would be no difficulty in obtaining a filled thermometer bulb without any scale, such as I have just described ; but if one cannot be procured the same observations may be made with an ordinary thermometer, neglecting for the present the graduations. (In purchasing a thermometer be sure to have a *mercury one, not alcohol*. If possible, procure one marked on the one side with the Fahrenheit scale, and the Centigrade scale on the other.)

With either the simple bulb or a complete thermometer make the following tests : First, plunge the thermometer into very cold water ; notice that the mercury sinks in the stem. What is the reason of this ? The thermometer was at a higher temperature than the water, and so has given up heat to the water until the two acquire the same temperature. Next put the thermometer in warm water. The mercury rises, and after a while becomes stationary : in this case the water was the warmer of the two, and imparts heat to the thermometer until the two are at the same temperature. If in the next place, the thermometer is put into still hotter water, the mercury rises yet further in the stem, until once more the thermometer and water are equal in temperature. Now, we learn this much about the behaviour and use of the thermometer : Whenever it is placed in contact with any other body the two acquire the same temperature, and, as mercury has a definite volume for various temperatures, some idea of the temperature of a body is gained by observing the volume of the mercury as shown by its rise or fall in the stem of the instrument. When the temperature is comparatively high the mercury stands high in the stem, and with cold bodies it sinks correspondingly low. Further, if the thermometer is put into, for example, two vessels of water, and stands at the same height in each, we know that the water in these two vessels is at the same temperature.

33. Thermometric Scales.—Before we can make much further use of our thermometer, it is absolutely necessary to have some sort of scale attached to it. In order to construct a scale there must be some fixed points from which to start, just as in a set of weights you must have one, as the ounce, for a commencing point. Take either the thermometer bulb or a complete thermometer, and dip it in a mixture of small pieces of ice with water. Let it stay in this mixture until the mercury is stationary, taking care to keep the water well charged with ice and thoroughly stirred. Mark the place where the mercury stood, and repeat the experiment some other day: the mercury again stops just in the same place. We know, then, that this mixture of ice and water is always at the same temperature. Next heat some water to the boiling point in a clean iron pan, and put in the thermometer: the mercury rises and again becomes stationary. Here, again whenever the experiment is tried under the same conditions, the mercury stands at the same point. The first of these temperatures is known as the freezing point of water, or the melting point of ice. The second is the boiling point of water. When proper precautions are taken, into which we need not now enter, the temperatures at which ice melts and water boils are constant. The "freezing" and "boiling" points are marked on most thermometers. The next thing is to construct a scale for temperatures which do not coincide with these fixed points: there are unfortunately several such scales in existence. The simplest and most sensible is that in which the distance between freezing and boiling points is divided into a hundred equal parts or degrees. The freezing point is than called O, and the boiling point 100: temperatures above the boiling point simply go on counting upwards. Temperatures below the freezing point are counted in degrees reckoning downwards, the degrees being of the same value.

Thus, a temperature that is 10 degrees below the freezing point is termed—10° (that is, minus 10 degrees). The colder the temperature, the greater the number of minus degrees, or degrees below the freezing point. This scale is known as the Centigrade, or hundred-degree scale, and is that used in most European countries, and almost universally for scientific purposes.

Another scale is, however, used in England to a greater extent, and that is the Fahrenheit scale. Fahrenheit divided the distance between the freezing and boiling points into 180 degrees, and measured off degrees of the same value both above and below the boiling and freezing points. At the time that he constructed his scale, with the greatest cold attainable, he caused the mercury to descend 32 degrees below the freezing point. Fahrenheit took that point as the zero or 0° of his scale and then reckoned upwards. The freezing point, being 32 degrees above the zero, is called 32° in this scale, and as the boiling point is 180 degrees above the freezing point, it amounts to 32 and 180 added together, which give 212° for the boiling point. The degrees below the zero are reckoned as minus, or—. degrees. Thus—15°F. means 15 degrees below the zero, or 47 degrees below the freezing point. There being these two scales in use, the baker should know how to calculate degrees of the one scale into those of the other. Let us see how this can be done. Now we know that 100 Centigrade degrees are equal to 180 Fahrenheit degrees, and consequently that 5 Centigrade degrees equal 9 Fahrenheit degrees. Further, 1 Centigrade degree is equal to $\frac{9}{5}$ of a Fahrenheit degree, and 1 Fahrenheit degree equals $\frac{5}{9}$ of a degree Centigrade. Supposing a Centigrade thermometer stands at 15°, and we wish to know how much that is Fahrenheit; as 1 degree Centigrade equals $\frac{9}{5}$ degree Fahrenheit, 15°C. must be 15 times $\frac{5}{9}$:

$$\frac{9}{5} \times 15 = 27 \text{ degrees Fahrenheit.}$$

(In order to multiply a fraction, the upper figure or numerator is multiplied by the whole number, and then the result divided by the denominator, or lower number.)

But 15°C. is 15 degrees above the freezing point, and is equal to 27 degrees Fahrenheit above the freezing point. As the freezing point, Fahrenheit, is 32, we must add on 32 to our result, which make it 59°F. In works on arithmetic this calculation is expressed by

$$\frac{C.^\circ \times 9}{5} + 32 = F.^\circ$$

This means that Centigrade degrees must be multiplied by 9 and divided by 5 ; 32 must then be added, and the result is the temperature on the Fahrenheit scale.

To change temperature Fahrenheit into temperature Centigrade, the reverse operation must be performed. You must first subtract 32, then multiply by 5 and divide by 9 the result is temperature Centigrade. This is shown in the following manner :

$$\frac{(F.^\circ - 32) \times 5}{9} = C.^\circ$$

The following table gives the corresponding number of degrees on the two scales for the same temperature :

Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.
—17.7	0	70	158
0	32	75	167
15	59	80	176
15.5	60	85	185
20	68	90	194
21.1	70	95	203
25	77	100	212
26.6	80	150	302
30	86	200	392
32.2	90	232.2	450
39	95	250	482
40	104	260	500
55	131	287.7	550
60	140	300	572
65	149		

34. Quantity of Heat.—In estimating heat it is not sufficient to speak of temperature, as a little consideration will show. Suppose you take a quart of boiling water in one vessel and 4 quarts in another, both will be at the same temperature, yet the latter must evidently contain more heat than the former, because there is more of the boiling water in it. Or one might vary the suggested experiment in this way : Take a quart of boiling water in the first vessel and 3 quarts of boiling water in the second, and next add to the three quarts

1 quart of cold water. The water in the second vessel will now be at a lower temperature than that in the first, and yet the whole quantity of water contains more heat than the quart of boiling water in our first vessel. You will see, then, that temperature is not the only heat-measure with which we have to deal, because one vessel may be at a higher temperature than another and yet contain less heat. In addition to temperature or intensity of heat **we have to measure the Quantity of heat a body possesses.** Now, like temperature, heat quantity must be measured by the effect it is capable of producing, and according **the measure of heat quantity, or "unit of heat," is taken as that amount of heat necessary to raise one part by weight** (for example, 1lb.) **of water from 0° to 1° Centigrade.** Or, if we like, we may substitute from 32° to 33° Fahrenheit for the degrees Centigrade.

Now let us see what use we can make of this measure of heat. If we have a pound of water at 0°C. it will require one heat unit (1 H.U.) to raise it to 1°C. If we have 2lbs., of water 2 H.U. will be required to raise them from 0° to 1°C. Or, if we have 1 lb. of water at 0°C., and wish to raise it to 2°C., we shall again require practically 2 H.U. Although not quite the same amount of heat is required we may assume for our present purpose that just the same amount of heat is required to raise 1 lb. of water through 1° at any temperature between the freezing and the boiling points. Now, whatever quantity of water we have, if we multiply the weight in pounds by the number of degrees through which we wish to raise it, that will give us the number of units of heat required. Suppose, for instance, we have 20 gallons of water at 15°C. and require to raise them to 40°C., how many units of heat are required?

Now, as a gallon of water weighs 10 lbs., we have altogether 200 lbs. of water. Further, in raising it from 15° to 40°, the rise in temperature is 25°; and multiplying 25 by 200 we have 5000 heat units required to raise 20 gallons of water from 15° to 40°C. This may also be expressed in the following manner:

$$20 \times 10 \times 25 = 5000 \text{ H.U.}$$

In cooling, the water would yield exactly the same quantity of heat as was required to raise it in temperature.

35. Useful Heat Calculations.—There are many operations in bread-making which require calculations of temperature. Perhaps the very simplest is that of reckoning the temperature of a mixture of two lots of water, each of which had originally different temperatures—thus, if 5 gallons of water at 10°C. are mixed with 5 gallons at 20°C., the temperature of the mixture will be 15°C. : that is, halfway between those of the two lots before mixing. It will be well, however, to work this out in this way : the second lot of water being 50 lbs. at 20° is 10° hotter than the first, or contains 10 × 50=500 H.U. more than the former. When they are mixed, these 500 H.U. are spread equally over the whole of the water, and being divided between 100 lbs. of water, give 5 H.U. to each pound ; that, as we know, is sufficient to raise the temperature 5°—that is, from 10° to 15° C. Now, this may seem a roundabout way to get at this result, but I want to explain the principle, so that you may apply it in rather more difficult cases. We will next take an example on the Fahrenheit scale. You have 20 gallons (200 lbs.) of water at 60°F., and mix with them 5 gallons at 90°F.—what will be the temperature of the mixture ? Here again, the thing is to find out what extra heat the hotter water contains, and how much it will heat the lot when distributed over the mixture. The hot water is 30° higher in temperature, and there are 50 lbs. of it—that is, there are 50 × 30=1500 H.U. to distribute over the whole of the water, of which there are 25 gallons, or 250 lbs. Dividing 1500 by 250 we have

$$\frac{1500}{250} = 6 \text{ H.U. to each pound of water.}$$

As 6 H.U. raise 1 lb. of water through 6°, and the colder water was at 60°, the temperature of the mixture is at 66° F. Stating this as simply as possible : in order to determine the temperature of a mixture—*First, calculate how many units of heat the hot water possesses more than it would at the temperature of the colder water. Then divide these up among the whole of the water mixed, in pounds : the result is the number of heat units each pound of water will receive. As 1 h.u. raises the temperature of 1 lb. of water through 1°, add this amount to the temperature of the colder water, and the result is the temperature of the mixture.*

Let us next take another calculation, which may well arise in a bakery. You have 15 gallons of water at 55°F., and require to raise the temperature to 80°F.—what quantity of boiling water must you add? We before worked out one rule from the calculation: it may be a help to now alter our course of proceeding, and first give the rule. *First, calculate how many heat units are required in order to raise the quantity of water to the desired temperature: then calculate how many heat units a pound of hot water at any temperature given will yield in cooling to the temperature required. Divide the number of heat units necessary to warm the cold water by the number each pound of hot water can yield in cooling, and the result is the number of pounds of hot water required.*

In our question, 15 gallons (150 lbs.) are to be raised from 55° to 80°F.=25°, then 150 × 25=3750 H.U. required to raise the temperature of the cold water. One pound of boiling water in cooling to 80° will give out 212—80=132 H.U.; but altogether the hot water is required to provide 3750 H.U., then

$\frac{3750}{132}$=28 lbs., or $2\frac{8}{10}$ gallons of boiling water necessary.

Again, another calculation, and this time one which in bakeries, working on modern lines, is frequently an absolute necessity, if regular results are to be obtained. For a batch of bread you require altogether 20 gallons of liquor, at a temperature of 90°F., of this, 6 gallons consist of either a ferment or other special preparation which has a temperature of 60°F., the remainder being water. At what temperature must the water be taken so that the mixture shall have the desired temperature of 90°F.? Taking the lowest temperature as a starting point, which in this case is that of the 6 gallons at 60°F., we must find how many heat units the mixture as a whole requires above those it would contain at that temperature. We require 20 gallons (200 lbs.) at 90°—that is, at 30° over the lowest temperature concerned; altogether this gives

200 × 30=6000 H.U.

Now these 6000 H.U. must be supplied by the added water, of which 14 gallons (140lbs.) are required. Dividing 6000 by 140 we have

$$\frac{6000}{140} = 43 \text{ H.U., to be supplied by each pound.}$$

That is, each pound must be 43° above 60°F., which equals 103°F. as the temperature at which the water must be taken.

Giving the method of making the calculation in the form of a rule—*Starting from the lowest temperature concerned, find how many heat units are required to raise the whole mixture from that point to the desired temperature. Then divide the result by the number of pounds of water it is required to add; add on this figure to the lowest temperature taken as a starting point, and the result is the necessary temperature for the added water.*

36. Specific Heat.—Although the result of mixing a pound of water, at say 50°F. with a pound at 100° F. is to yield a mixture of 2 lbs. at 75° F., it must not be taken for granted that the same result would follow on mixing different materials. Thus if a pound of water at 50° is mixed with a pound of quicksilver at 100°F., the two after mixing are not at a temperature of 75°, but only a little over 50° This at first sight seems strange, but the explanation is that to raise different bodies through the same number of degrees of temperature widely differing quantities of heat are required. Of course from this it follows that different substances in cooling give out varying quantities of heat. There is a very simple experiment that shows this fact most strikingly. Get two balls of the same weight, one of copper and the other of lead, say each ½lbs. Have also ready a jar full of lard. Heat the balls in a saucepan of boiling water, and in two or three minutes take them out with a pair of tongs and at once drop each on the lard. The hot ball sinks into the fat, melting as it goes down, until at last the ball is quite cooled. Observe the distance which each descends into the lard: the copper ball will be found to have melted its way much farther than the lead. In fact, to raise copper through 1°, about three times as much heat is required, weight for weight, as is the case with lead. Of all liquids and solids, water requires the greatest amount of heat to raise it through a degree of temperature. **The quantity of heat necessary to raise 1-lb. of water through 1° being taken as 1, the amount of heat necessary to raise 1-lb. of any other**

substance through the same temperature is termed the Specific Heat of that substance.

37. Specific Heat of Flour.—The most important mixture to the baker is that of flour with water. While we have found that equal quantities of water mixed at two different temperatures yield a mixture which has a temperature intermediate between the two, we shall find that the same does not hold good with regard to mixtures of flour and water. The following are the results obtained in some experiments made on the subject for the purposes of this book. In the first series the flour was weighed in grams, of which there are rather over 28 to the ounce :

No.				Specific Heat.
1.	300 grams of water at	120° F.	— 600 at 88° F.	—
	300 ,, ,,	64° F.		
2.	500 grams of water at	130° F.	— 1000 at 101° F.	0.74
	500 ,, flour at	62° F.		
3.	300 grams of water at	89° F.	— 860 at 81° F.	0.23
	560 ,, flour at	63° F.		

In the first mixture, that of two lots of water, the actual temperature was 88°, being 4° less than the calculated temperature, which is 92° ; the 4° represents, of course, heat which has been lost by cooling during the experiment. In the second experiment, if the mixture had been of two quantities of water, the resultant temperature would have been 96°, and in the third 72°, calculating the temperatures in the manner previously described. It will be seen, however, that the doughs are in each case considerably hotter : from this we learn that **a given weight of flour requires less heat to raise it from one temperature to another than does the same weight of water.** Let us calculate what the actual amount of heat, or specific-heat, is in the preceding experiment. In No. 2 test, 500 parts of water have been cooled from 130° to 101°, that is through 29° We find the number of heat units evolved by multiplying, thus :

500 × 29=14,500 heat units.

These have raised 500 grams of flour from 62° to 101°, that is, through 39°, which may be considered equivalent to

500 × 39=19,500 grams raised through 1°.

Now, as 19,500 grams of flour require 14,500 heat units to raise them 1° in this experiment, it is easy to calculate how much 1 gram of flour would require :

$$\frac{14,500}{19,500} = 0.74 \text{ of a heat unit.}$$

The actual specific heat as deduced from these two experiments is given opposite each. Before saying anything further about them, I will next give the results of a series of tests made in the bakehouse on large quantities of flour and water. The doughs were machine mixed, and no allowance is made for the added salt and yeast, which latter was a brand of the compressed variety. The quantity and temperature of the water and flour are given, and also the temperature of the dough. In another coloumn is placed the specific heat of the flour as calculated from each experiment.

	WATER.			FLOUR.		DOUGH.	FLOUR.
No.	Quarts.	Lbs.	Temp.	Lbs.	Temp.	Temp.	Specific Heat.
4	53	132.5	95°	205	52.5°	79.0°	0.39
5	51	127.5	90°	205	50.0°	77.0°	0.30
6	51	127.5	90°	205	50.0°	77.0°	
7	53	132.5	98°	205	53.0°	79.0°	c.45
8	15	37.5	98°	56	52.0°	79.5°	0.50
9	53	132.5	89°	205	53.0°	76.0°	03.6
10	53	132.5	89°	205	53.0°	76°.0	

As an illustration of the mode of calculation, it will be well to work one example, which shall be No.4. We find that 132.5 lbs. of the water have fallen from 95° to 79°, that is, through 16°.

$$132.5 \times 16 = 2120 \text{ H.U. evolved by the water.}$$

Then, 205 lbs. of flour have been rasied from 52.5° to 79°, that is, through 26.5°.

$$205 \times 26.5 = 5432.5 \text{ lbs. raised through } 1^{\circ}.$$

$$\frac{2120}{5432.5} = 0.39 \text{ of 1 H.U. to raise 1 lb. of flour through } 1^{\circ}.$$

The others have been calculated in precisely the same manner. Now, looking over the whole series it will be observed that there are considerable discrepancies. In No. 2 there was required as much as 0.74, while No. 3 worked out at the remarkably low figure of 0.23. This latter was a very stiff dough, and instead of being mixed with a stirring rod had to be kneaded by hand: undoubtedly as a result the temperature was increased by heat derived direct from the warmth of the hand. In consequence, this particular result is not so trustworthy as the others. Still, No. 1 differs considerably from the remaining numbers of the series. It will be seen, however, that the specific heat increases as the temperature of the resultant dough increases. The group of Nos. 4, 7, and 8, in which the dough is at temperatures from 79° to 79.5° has a specific heat of from 0.39 to 0.50. The group of Nos. 5, 6, 9, and 10, in which the dough is at temperatures from 76° to 77°, has a specific heat of from 0.30 to 0.36. We see, further, that in No. 2, in which the dough is at 101°, the specific heat is 0.74. As these latter experiments were made in the bakehouse, it follows that the temperatures are really those of practical working, and, as before said, no allowances are made for effect of salt, yeast, &c. Further, apart from the specific heat of flour, the results are further complicated by certain chemical actions which go on when these bodies are mixed. These are certain to cause some irregularities in the results; but as you want to study this matter, not as it appears in the chemist's laboratory, but in actual working, it is far better to take the results as they are. After allowing for small discrepancies, we see the tests bear out the following general statement—The Specific Heat of flour increases with the temperature; or, **the higher the temperature of the dough the more heat is required to raise the flour through each succeeding degree of temperature.** In practical working, with doughs at about 80°F., it may be assumed that the specific heat of flour (including variations due to cooling, chemical action, &c.) is about 0.45.

Let us see one important use that may be made of this figure. It is no unusual thing to find that a baker carefully measures the temperature of his water, but does not do so with his flour. In consequence, suppose him to be working with flour that has for some time been stored in his bakery, such flour will probably be at from 60° to 70°. Now, if, especially in winter, a new lot is brought in from the warehouse, it may be down to perhaps 32°; the result is that the doughs are colder and work badly, being, in fact, starved through the cold flour. This is more likely to happen in a machine bakery than a hand one, because when dough is mixed by hand the first plunge of the arm into the flour shows how cold it is. With the machine it is quite possible that the dough is scarcely touched until ready for scaling and moulding. It is most important, for this reason, that the temperature of the flour should be carefully watched. Suppose that after mixing No. 4, the next batch was required to be exactly like it in temperature, but that the flour to be used for it was at 31.5°F. instead of 52.5°, what temperature should the water have? Under these circumstances, 250 lbs. of flour are 21° colder in the latter batch. The first thing is to find out how much heat is necessary to warm up this flour to 52.5°. If it were water 205×21 would give the number of heat units, but as we take it that each pound of flour through 1° requires only 0.45 H.U., then we have

$$205 \times 21 \times 0.45 = 1937.25 \text{ H.U. required.}$$

Then, as we have 132,5 lbs. of water,

$$\frac{1937.25}{132.5} = 14.6 \text{ H.U.,}$$ each pound of water will require

in addition to that in test No. 4.

But we know that this means that each pound must be 14.6° hotter, and as the water in No. 4 was at 95°, it would have to be in this case at

$$95 \times 14.6 = 109.6°\text{F.}$$

Putting the two results together we have

Water.		Flour.		Dough.
Llbs.	Temp.	Lbs.	Temp.	Temp.
132.5	95°	205	52.5°	79°
132.5	109.6°	205	31.5°	79°

With these proportions, it will be seen that the flour, being 21° colder, the water is required to be 14.6° hotter. From this may be deduced, as a general rule sufficiently near for practical purposes, that for every 3° the flour is hotter or colder than usual the water must be 2° colder or hotter than usual in order to attain the unifom dough temperature.

38. Sources of Heat.—Practically all heat employed in various operations in the arts and manufactures is derived from the sun. This is self-evident in the case of ripening grain. We all know that comparative absence of the sun's heat means the difference between a good harvest of ripe, dry wheat and a bad one of damp; immature grain. But when we remember that all substances we use as fuel are of vegetable origin, it will be seen that here again we are utilising the heat of the sun; for it is that which has caused the tree to grow whose dead branches may be used for heating our ovens. Similarly, coal is but the fossil remains of trees which grew and flourished some hundreds of thousands of years ago, and have since lain buried under rocks accumulated through successive ages. Coke is simply the residue of coal from which coal gas has been prepared. The combustion of one or other of these fuels is the baker's immediate source of heat.

The nature of combustion has already been explained; and also the fact has been stated that **the amount of heat evolved by the combustion of a given weight of any substance is always the same.** Below are given the number of heat units evolved by the combustion of one gram of each substance in air or oxygen.

HEAT DEVELOPED DURING COMBUSTION.

Substance.		Heat Units.
Hydrogen		34,462
Carbon		8,080
Sulphur		2,220
Carbon Monoxide		2,634
Marsh Gas		13,063
Olefiant Gas		11,942
Alcohol		6,909
Welsh Coal	about	8,241
Newcastle Coal	,,	8,220
Derbyshire Coal	,,	7,733
Coke	,,	7,000
Wood (dried in air)	,,	3,547

It will be seen from this table that hydrogen, weight for weight, gives off by far the most heat during combustion; the second place being taken by carbon. Among the compound gases, carbon monoxide is of great importance so far as the baker is concerned. When carbon is burned in a deficient supply of air or oxygen, the following change takes place:

$$\begin{array}{ccccc} 2C & + & O_2 & = & 2CO. \\ \text{Carbon.} & & \text{Oxygen.} & & \text{Carbon Monoxide.} \end{array}$$

This gas, in the presence of air, burns further according to the following equation:

$$\begin{array}{ccccc} 2CO & + & O_2 & = & 2CO_2. \\ \text{Carbon Monoxide.} & & \text{Oxgyen.} & & \text{Carbon Dioxide.} \end{array}$$

Let us examine for ourselves the quantity of heat evolved at each of these two stages. Now, from the formula, CO, it will be seen that 1 gram of carbon yields $\frac{28}{12}$ of its weight of carbon monoxide.

$$\frac{1 \times 28}{12} = 2.33 \text{ grams of carbon monoxide.}$$

As 1 gram of carbon monoxide evolved during combustion 2634 H.U., 2.33 grams must evolve.

$$2634 + 2.33 = 6146 \text{ heat units.}$$

So that the carbon monoxide produced from one gram of carbon evolves, on burning, 6146 heat units : but as if 1 gram of carbon, when burned direct to carbon dioxide, yields 8080 H.U., then in burning to carbon monoxide the gram of carbon must evolve

$$8080 - 6146 = 934 \text{ heat units.}$$

Summing these results up, we have—

Heat produced by 1 gram of carbon burning to carbon monoxide	1934 heat units
Heat produced by the combustion of the carbon monoxide yielded by 1 gram of carbon	6146 heat units.
	8080

This point is thus explained at length because of the important practical bearing it has to the consumption of fuel in many forms of patent oven. The furnaces of such ovens are provided with doors. If these be entirely closed during work, the air, as has been previously explained, passes up through the fire and forms carbon monoxide, which passes unburned up the oven flue, and thus causes the loss of the whole of the heat which would have been evolved by its combustion. The remedy already suggested, is to keep the furnace doors slightly open ; the slight indraught of air effects the combustion of the carbon monoxide on the upper surface of the fire.

39. Mechanical Production of Heat.—It should also be mentioned that heat can be obtained from mechanical sources ; thus, wherever force is consumed by friction, heat is evolved as a result, and the rubbing bodies are raised in temperature.

40. Effects of Heat.—Among the principal effects of heat are

1. The expansion of solid, liquid, and gaseous bodies.
2. The liquefaction of solids and the vaporisation of liquids.

It has already been mentioned that an increase of heat causes bodies to expand (except in a few rare instances), solids expand least, liquids more, and gases most of all. Each particular solid and liquid has its own rate of expansion, and in the act of expanding exerts enormous force.

All gases, on the other hand, expand at the same rate if kept at the same pressure. Thus if two small balloons are half filled with oxygen and hydrogen respectively and placed in the same room, where each is subjected to the same atmospheric pressure, and then both are warmed, they will expand at the same rate for equal increase in temperature. But if the gases are kept in vessels which do not permit expansion, such as air-tight metal cylinders, then the increase in temperature simply causes an increase in the *pressure* exerted by the gases. The rate at which gases expand may be stated in the following way : Suppose we take a temperature 273°C. below the freezing point, and call that point the absolute zero of temperature, and temperatures reckoned from it absolute temperatures ; then 0° and 100°C. would be respectively 273° and 373° absolute temperature. The effect of temperature on the volume of gases is thus expressed : **The pressure remaining the same, the volume of a gas is in direct proportion to its absolute temperature.** As an illustration, let us see what increase in volume would be caused by the heat of an oven on the gas contained in dough, if it were during the act of baking to be raised to the same temperature as boiling water. Suppose the dough is at a temperature of 25°C., that of boiling water is 100°C.

$25 + 273 = 298^\circ$ absolute temperature.
$100 + 273 = 373^\circ$,, ,,

Then as $298 : 373 :: 1 : 1.25$ = volume of the gas at 225°C.

That is to say, 100 cubic inches of gas at 25°C. (77°F). will have become 125 cubic inches at 100°C. (212°F.). The great expansion of dough, during baking, is in part caused by the rise in temperature of the gas contained within the loaf.

If the gas is enclosed so that it cannot expand, then its pressure increases at the same rate with a rise in temperature, as does its volume when the pressure remains the same.

The most important instance of liquefaction and vaporisation as produced by heat is that of water; it will be well therefore to examine this somewhat carefully.

41. Action of Heat on Water.—Let us assume, for this purpose, that we start with ice, taking a piece at a temperature considerably below the freezing point, and applying a constant source of heat. The ice first expands as heat is applied, and rises in temperature until 0°C. (32°F.) is reached. At this stage the temperature remains stationary until the whole of the ice is melted. The heat is during this time employed in doing the work of altering the condition of the substance from the solid state of ice to the liquid one of water; in consequence, such heat does not raise the temperature. Supposing the piece of ice to weigh 1 gram, 79 heat units will be absorbed in changing it from ice at 0°C. to water at the same temperature. During the act of melting the volume considerably diminishes, for 10.9 volumes of ice produce only 10 volumes of water. The whole of the ice being melted, further application of heat causes a steady rise in temperature, and also a *diminution* of volume, until 4°C. (39.2°F.) is reached: as the temperature still further rises the water commences to expand. As water at 4°C. expands on being either heated or cooled, this temperature is termed that of the *greatest density* of water, as then a given weight occupies the least space. With continued application of heat the temperature steadily rises until 100°C. (212°F.) is reached, at the same time expansion proceeds regularly. When this temperature is attained the water commences to boil, and is entirely changed into steam by a continued application of heat. The temperature remains constant while any water is left. Again, the heat has been employed in altering the condition of the water from the liquid to the gaseous state. If a note be taken of the time necessary to raise the water from the freezing to the boiling point, it will be found that the time necessary to boil it all away is over five times as much. Careful observations show that to convert 1 gram of water into steam 537.2 Centigrade, or 967 Fahrenheit, heat units are required. The volume of the steam is many times greater than that of the water ; roughly speaking a cubic inch of water is said to produce a cubic foot of steam. The steam rises in temperature and expands under further application of heat, obeying just the same laws as do other gases.

Steam in cooling passes through a series of changes which are just the opposite of those it experiences on being heated ; it gives out just the same quantity of heat in changing from steam to water as was required to convert the water into steam ; further, in solidifying the water evolves the same amount of heat as was necessary in order to effect its liquefaction.

Where pure steam can be obtained in a bakery (that is, steam from clean water free from oily and other foreign matters), it may often be advantageously employed for heating purposes. Thus, a quantity of water can be quickly raised to the boiling point in an ordinary wooden tub by leading a jet of naked steam into it through a piece of hose. The quantity of water as steam necessary for this purpose may be easily calculated. To heat 10 gallons of water at 60°F. to the boiling point, what quantity of water as steam is necessary ? 10 gallons=100lbs. have to be raised from 60° to 212°=152°

$$100 \times 152 = 15{,}200 \text{ H U. required.}$$

1 lb. of steam, in condensing, evolves 967 H.U. Therefore

$$\frac{15{,}200}{967} = 15.7 \text{ lbs. of steam required.}$$

As 15.7 lbs. are just over $1\frac{1}{2}$ gallons, the 10 gallons at 60° will be increased to a little over $11\frac{1}{2}$ gallons by being boiled in this way. In practice, allowing for loss of heat, it may be safely assumed that 10 gallons thus treated will yield 12 gallons of boiling water.

Not only is heat required to liquify ice, but also other solid substances ; when salt is dissolved in water it assumes a liquid condition, and hence lowers the temperature of the water by the amount of heat required to change salt from the solid to the liquid form.

42. Effect of Pressure on the Boiling Point.—So far, in dealing with the boiling point, it has been taken for granted that water has been boiling under atmospheric pressure, or simply in the open air. By, however, altering the pressure, the temperature of the boiling point is also altered; thus in a space from which air is exhausted water boils at a much lower temperature than in the air. On the other hand, when the water is confined, as it is in a steam boiler, the steam, by gradually accumulating, exerts a pressure on the water which may become enormous. **As the pressure increases the temperature of the boiling point is raised.** The following table gives the pressure of steam in lbs. per square inch, together with the corresponding temperature of the boiling point.

Approximate Pressure.	Temperature of Boiling Point.	
15 lbs.	100° C	212° F
70 ,,	150° ,,	302° ,,
231 ,,	200° ,,	392° ,,
413 ,,	230° ,,	446° ,,

Use is made of the great temperature of steam under high pressure in the construction of steam ovens. The tubes of these are of great strength, and contain, welded up within them, a certain quantity of water. On heating the ends of the tubes, which project into the furnace, this water boils, and its steam, being confined, gradually becomes sufficiently hot to raise the temperature of the oven itself to the baking point.

43. Transmission of Heat.—We all know that when one part of a body or place is heated the other parts also become hot more or less quickly. It will be necessary for us to know something of how heat is thus transmitted from place to place. **There are three methods by which heat can be transmitted from one point to another, which are termed respectively Convection, Conduction, and Radiation.** Explanation and examples of each of these are given.

44. Convection.—In this mode of transmission of heat, the heat is conveyed from point to point by the actual movement of portions of the heated body from one place to another. Distribution of heat by convection can only occur in liquid or gaseous bodies. The method by which a mass of water becomes hot is one of the most familiar, and at the same time most striking instances of heating by convection. Where a glass flask is obtainable, the following experiment shows how a mass of water becomes hot. Fill the flask with water, and add a small quantity of bran ; shake up until the bran is thoroughly wetted and sinks slowly to the bottom. Next place the flask over a Bunsen or atmospheric burner, and thus heat the water. Almost immediately the bran lying at the bottom of the flask rises to the top of the water through the centre of the flask ; it then turns over and falls down again to the bottom around the outside of the flask. All the while the water is being heated, there will be an upward current of water in the middle of the flask and a return or downward current on the outside. The object of the bran is to render the movements in the water visible. When the heat is first applied to the bottom of the vessel the particles of water in contact with it become heated ; they, in consequence, expand, and thus being lighter than the surrounding particles, float to the top ; their place is taken by the colder particles,and these in turn become hot and ascend. There is thus a continuous series of currents produced, which continue until the whole of the water is raised to the boiling point. If a thermometer be placed in such a vessel of water being heated, and held near the bottom and then near the top, there will be a rather higher reading in the lower position, but it will be found to register very nearly the same temperature in all parts of the water. We may say that the whole volume of water thus heated practically rises in temperature at just the same rate. Another method of proving this consists of taking a test-tube, filling it with water, and boiling it by heating the bottom in a Bunsen flame. On passing the fingers over the outside of the tube it feels uniformly hot from top to bottom. Next vary the experiment by once more filling the tube with cold water and holding it slantwise above the flame, so that just simply the upper portion of the water is exposed directly to the heat. The water in the upper part of the tube rapidly boils, while that at the bottom remains perfectly cold, which may be readily observed by passing the fingers over the outside. In this case no heating by convection can occur, because the heated and expanded water will rise, but not descend. In consequence of this property, it becomes necessary whenever water is being heated to place the source of heat at the lowest point. For example, bakeries are now often fitted with attemperating tanks in which water at just the right temperature for setting the sponges and doughs is prepared. These tanks are fitted with a hot and cold water supply. The hot water must enter at the bottom and the cold at the top. Then if it be required to raise the temperature slightly,a small quantity of hot water added at the lower part of the vessel rises toward the surface and so evenly warms the whole mass. Or if it be required to cool the water, the addition of a little cold water on the top results in its sinking through the rest and thus evenly cooling it. Hot water added at the top would simply float there, and cold water added at the bottom would remain, without rising, as a bottom layer ; in neither case would they affect (except very slowly) the temperature of the main body of water. It is the same principle which governs the heating of water in a large tank by means of a boiler placed over the furnace of an oven. The tank must be at a higher level, and there are flow and return pipes ; the hot water ascends through one pipe rising from the top of the boiler, because of its greater lightness, and the cold water descends through the other.

When it is required to cool water artificially, for the same reasons, the source of cold (or more exactly, the means of abstracting heat) must be applied to the upper surface. Thus at times water for baking purposes is cooled by means of ice, pails containing that substance being floated in the water tank. The ice cools the upper layer of the water, this sinks owing to its having contracted, and the warmer portions rise to the surface.

Currents in air may be produced in very much the same way as those in water, for air on being heated expands and rises, and cold air descends to take its place. For efficient ventilation provision should be made for the escape of hot air from the upper part of a room, and the admission of cold air at the lower.

From the various instances given as illustrations, it will be seen that **Convection is a mode of distributing heat through a mass of either liquid or gas by means of moving currents, such currents being usually produced by differences in density due to expansion caused by the source of heat itself.**

45. Conduction.—Not only can a liquid be made hot throughout its whole mass by the application of heat to one point, but so also can a solid. Thus, if the end of an iron poker to be placed in the fire, the other end also becomes,after a time, decidedly hot. In this case, evidently, the transmission of heat is not due to convection, because it would be impossible to set up currents in a solid body. Further, we find that it makes no difference to the rate at which the farther end of the poker becomes hot whether it be higher or lower than that in the fire, while it has already been shown that it makes a great difference in the case of a liquid whether the heat is applied at the upper or lower portion. In such cases as that of the poker, the heat is transmitted by conduction. **Conduction is that method of transmitting heat in which the heat passes from the hotter particles of a body to the colder ones lying in contact with them, and so throughout the whole body.** The student should take care to clearly see the difference between this and convection ; in the latter, by a series of currents, every part of the mass in turns comes in contact with the source of heat ; but with conduction the heat is communicated by actual transference from one particle to another lying beside it.

Conduction depends on the fact that in any one body or series of bodies in contact, the heat present tends to so distribute itself that all portions of the body, or series of bodies in contact, shall be at the same temperature. Going back to our experiment with the poker ; if not only a bar of iron but also one of copper and another of wood have their ends placed in the fire together, it will be found that the outer extremity of the copper gets hot much more rapidly than that of the iron, while the wood gets hot much more slowly. We find, therefore, that not only do substances conduct heat, but that **some substances conduct heat much more rapidly than others.** So marked is this difference that bodies have to be classified into conductors and non-conductors : the very worst conductors are not, however, quite destitute of conducting power. Speaking generally, the metals are comparatively good conductors, while clay and earthy substances generally conduct heat badly. Most bodies of animal or vegetable origin are bad conductors of heat. In the following table the relative conducting power of some of the metals is given. Silver having the highest conducting power is taken as 100 :

Silver...	100
Copper	75
Iron	10
Lead	8

It is difficult to compare the conducting power of the metals with that of such bad conductors as earthy substances, but it may be stated that still calling silver 100, then marble has a conducting power of about 2, porcelain and brick-earth of about 1 each. Wood, straw, cotton, and wool are all very bad conductors, and have even less conducting power than brick-earth or porcelain. Water and most liquids are bad conductors of heat, hence, as in our experiment, a volume gets heated by convection. Mercury is a metal, and notwithstanding its being a liquid, conducts heat well; so that if the experiment of heating on the top of the tube had been tried with mercury instead of with water, the whole mass would have speedily got hot by conduction. Even with liquids such as water, however, a limited amount of heating by conduction occurs.

On entering a very cold room, and touching the various objects in it, one is struck by the great apparent difference in their warmth to the touch. Masses of iron or copper feel very cold, marble also cold but to a less extent; wood still less, and such things as blankets seem scarcely colder than the hand. Now if these bodies be next placed in contact with a thermometer they will all register the same temperature. The reason why they feel so different to the touch is that the metals are better conductors, and so rob the hand of heat more quickly because their first layers part with the heat very rapidly to those next to them. On the other hand, in a very hot room, as a Turkish bath, iron and metals generally feel much hotter—the order, in fact, is just reversed. In consequence of this difference in feel to the touch, there is an idea prevalent that iron, for example, is much colder than wood; the difficulty has, in fact, been raised that iron troughs chill dough, and so are objectionable. But as just pointed out, this idea of iron being colder is a fallacy, and such can be easily proved by experiment. One phase of the objection is to the use of iron in the construction of the troughs of dough-kneading machines. In order to meet this let the following experiment be made: Pour a certain quantity of hot water, say 10 or 15 gallons, into a wooden tub or dough trough, note its temperature on being poured in, and again after standing five minutes. Then do exactly the same thing with the trough of the kneading machine, and compare the falling-off in temperature in each case. The difference will be very little. The iron is the better conductor of the two, but its capacity for heat is so little that it absorbs only a very small amount of heat from the water. In the case where dough is allowed to stand in iron troughs for the purpose of fermentation,the circumstances are somewhat different. The iron will not itself *chill* the dough, but may allow it to be sensibly *chilled* by permitting the conduction and escape of heat through it, if the temperature of the outside air in the room be low. Wood has here the advantage of interposing a layer of extremely bad conducting material.

When we require heat to pass through a substance readily, as in boilers for heating water, we select a good conductor, such as one of the metals ; but when we wish to prevent the rapid passage of heat, bad conductors are chosen. Thus, the outside of a boiler and the steam-pipes are coated with a non-conducting coating. Troughs containing dough are covered over with flannel or blankets, which conduct heat badly. The walls and surroundings of ovens are commonly made of bricks and clay, both of which are very bad heat-conductors, hence the heat is well retained in the oven. It should be mentioned that air itself is an extremely bad conductor of heat, but nevertheless may exert considerable cooling effect by convection. Where a coating of air can be preserved around a body without any currents therein, it acts very efficiently. Blankets, and loose articles of clothing generally, owe a good deal of their value to the fact that they retain air in their pores. An interesting example of the non-conducting power of air is found in the properties of slag-wool. This substance consists of slag from the blast furnaces, which is really a rough kind of glass, blown into a substance resembling cotton wool in appearance. This is now employed as a coating for ovens, &c., and its efficiency depends on its retaining air within it, as a layer round whatever body is to be protected from loss of heat.

46. Radiation.—The explanation of radiation is somewhat difficult without going a little into the theory of the nature of heat. This much will probably be understood by the general reader. When a body is hot each separate particle or molecule is in a state of vibration,and the hotter a body is the more violently do its particles vibrate. Further, all space is filled by a sutstance called *ether*, and this is capable of being thrown into a wave-like state in somewhat the same fashion as the sea. Now, the particles of hot bodies, swing to and fro against this ether, set it in motion—produce waves in it, in fact. These ether waves, on striking against a cold body, tend to agitate its particles, and succeed more or less in also setting them in more violent vibration. In fact, they cause the particles of the colder body to become hot. **In this way heat passes from the one body to the other, not, however, as hot matter, but as a peculiar wave-like motion in the substance called ether. This is known as "Radiation" of Heat, and is independent of the temperature of the medium through which the radiation occurs.** The sun's heat reaches us by radiation, and notwithstanding its great power of warming, it traverses regions of space which it does not warm, and in which the cold is of the most intense description.

The first point about radiation is that it takes place in straight lines in all directions from the hot body. The next is that at the same temperature different bodies radiate heat at different rates. This difference depends in part on the material of the body, and in part on the condition of its surface. Supposing all the following substances to be maintained at the same temperature, then their radiating power will be represented by the number attached :

Lampblack (Soot)	100
Tarnished Lead	45
Polished Iron	15
Burnished Silver	2.5

Clay and brick surfaces are good radiators of heat ; so also are flannel and similar bodies.

But in order that any body may be heated by radiation, we not only have to have the heat radiated, but it must also be absorbed by the body heated. There is considerable variation in the capacity which bodies have for being heated by absorption, some being much better absorbers than others. The power of absorption is closely related to that of radiation for bodies which are good radiators are also good absorbers of heat ; in fact, the tables of relative radiating capacity give likewise the proportions in which the substances also absorb heat.

The question of radiation and absorbtion of heat is one of considerable importance to the baker, since all bread is baked by radiant heat. In an oven a part of the heat finds its way direct into the bread by conduction from contact with the sole ; the remainer of the work is done by the heat radiated from the crown. That this is so is shown by the fact that where loaves are close together, without touching, they do not get so highly baked as in other parts. The loaves shield each other from the rays of heat evolved from the crown of the oven. One very interesting point in connection with this is the relative merits of iron and brick work for oven-building. It is impossible, within the scope of this little work, to go far into the subject ; but there is no doubt that in order to radiate the same quantity of heat iron must be maintained at a higher temperature than is necessary with brick-work. It is possible that the actual character of the heat may in this way be modified.

CHAPTER III.

CONSTITUENTS OF WHEAT AND FLOUR.

47. Nature of the Wheat Grain.—The grain of wheat is the part designed as the seed, from which new plants grow on the seed being favourably placed in the earth. Everyone is familiar with the appearance of a grain of wheat. There is down one side a long crease by which the grain is almost cut into two parts. At the upper end of the grain a slight "fuzz" or hairy development is seen ; this is known as the "beard." At the lower end of the seed, and on the side opposite to the crease, may be noticed a portion of the grain which is much softer than the rest, and which may be easily scooped out with the finger nail ; this is the germ. On breaking a grain across, it will be observed that the greater portion consists of a floury mass. This is the part from which white flour is made, and is called endosperm. The whole grain is enveloped in a coating of woody fibre which, when stripped off, is known as the bran.

The following sketches of the appearance of the grain of wheat, as seen under the microscope, will be of assistance to the student. In order to thus examine the wheat, a very thin slice has been cut and arranged on a glass slide for microscopic examination. Figure No. 2 is a sketch of such a slice or section cut longitudinally (lengthwise of the grain). The grain is magnified to eleven times its actual length, or, as usual written, 11 diameters. The amount of magnification is thus expressed after each sketch:

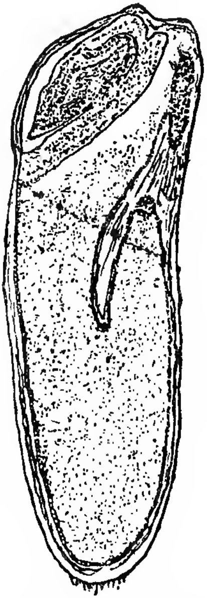


Fig. 2.—Longitudinal Section of Grain of Wheat.—11 diameters.

This was drawn with what is known as a 3in. objective. On the righ-hand side of the grain is seen the crease, the beard being at the lower end. At the opposite extremity is the germ, while the endosperm forms by far the greater part of the grain. The coating of bran is seen enclosing the whole.

48. The Germ.—The previous figure will have given some idea of the size of the germ compared with the whole grain. In Fig. 3 the germ is shown magnified to a greater extent. An inch objective was employed in this instance.

The germ is one of the most interesting parts of the whole grain, being the true seed or embryo; that is, the part from which the new plant is developed. Notice, first, that in cutting the section the outer skin has got somewhat detached from the germ itself. At *a*, what are called the cerealin cells of the bran terminate. The part marked *b* is called the plumula, and is the part from which the leaves and stem of the plant grow. The radicle or rootlet (*c*) is at the lower end, and from there penetrates into the ground and forms the root.

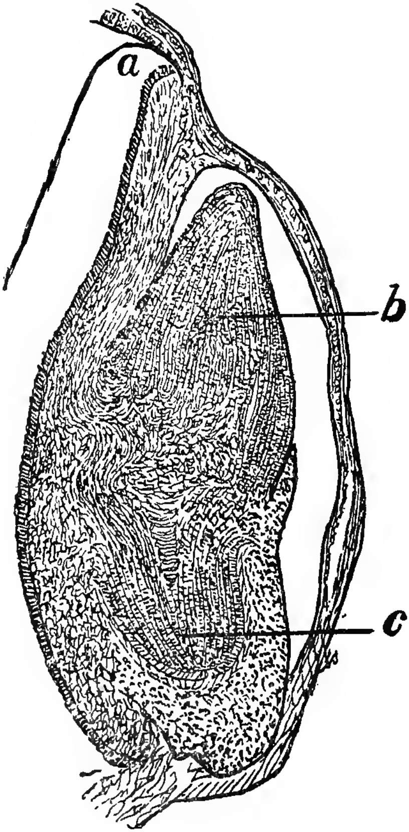


FIG. 3.—LONGITUDINAL SECTION OF GERM OF WHEAT.—32 diameters.

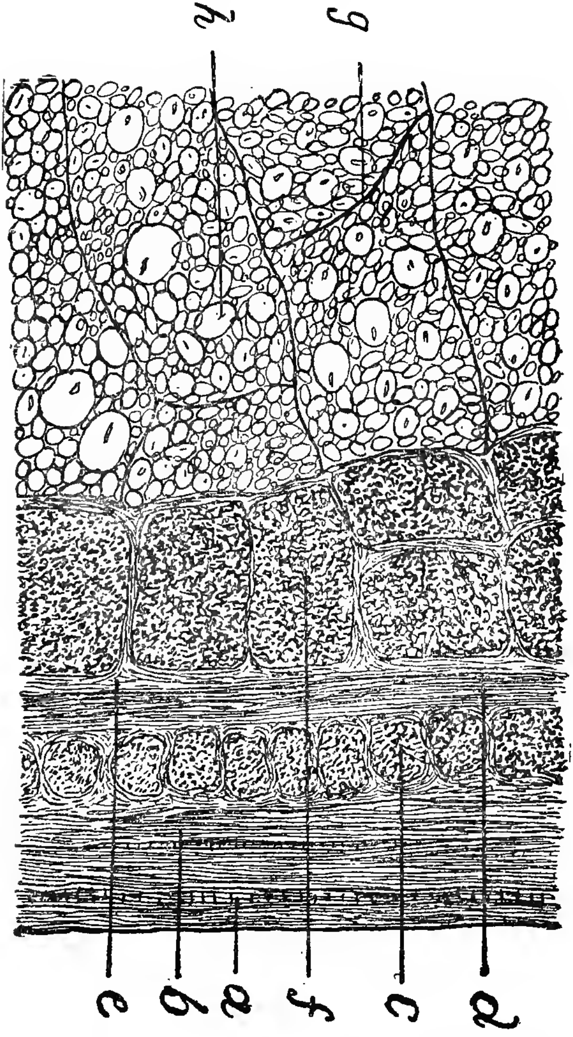
During the act of growing the germ requires nutriment before it can get it from the earth. This nutriment is supplied by the endosperm, and is largely absorbed by a peculiar series of cells lying between the germ and the endosperm. The natural use of the endosperm is to act as a source of food to the growing wheat plant.

49. Endosperm and Bran.—The structure of the endosperm requires higher microscopic power to see it properly. Fig. 4, p. 56, is a sketch made with a $\frac{1}{6}$in. objective, and passes through both endosperm and bran.

Let us first commence with the bran, which occupies rather more than half the view. Bran is composed of several more or less distinct layers arranged one over the other. The student will, of course, understand that this is a view of the bran looking at it edgeways. For particulars of the outer bran ayers, marked *a*, *b*, *c*, *d*, *e*, the reader is referred to the author's large work on *The Chemistry of Wheat, Flour, and Bread*; but mention must just be made of the large cells almost square in outline marked *f*. These are what are called "cerealin" cells, from a peculiar substance of that name which they contain. They form the inner layer of the bran. The endosperm is divided up into a number of irregular cells or portions by walls of delicate woody fibre or cellulose. The walls of one of these cells is marked *g*. These cells contain, packed away within them, little round or oval masses of starch, one of which is marked *h*. The interstices between the starch grains is filled principally with gluten.

50. Constituents of Flour.—Bearing in mind that ordinary white flour consists of the finely powdered endosperm of the wheat, with the bran and germ removed, let us try to find out something of its composition, and to do this we will suggest a series of experiments on a sample of flour.

51. Ash.—Take a little flour and spread it out on the bottom of a shallow platinum dish, and place it over a Bunsen gas flame. The flour speedily blackens and gives off a quantity of smoke, which soon takes fire. At last the flames go out, and there remains just a black mass. This is mostly composed of carbon, which we thus see is one of the constituents of flour. But we require to still go on heating, and as the carbon slowly glows away we have at last just a trace of a whitish grey substance remaining. This is the ash, or mineral part of the flour. If this ash is analysed it will be found to be mostly composed of potash, K_2O; magnesia,


h
g
e
b
a
f
c
d

MgO; and phosphoric anhydride, $P\frac{1}{2}O_5$; or putting it in other words, phosphates of potassium and magnesium. These phosphates are of great importance, because they are bone-forming, and help considerably in the building up and maintenance of the boney framework of the body.

52. Fat.—Thoroughly clean and dry a stoppered bottle of about 6 ozs. capacity, and about one-third fill it with dry flour. Next fill it to about two-thirds full with either ether or what is known as light petroleum spirit. These may be obtained from the chemist, and must be used very carefully, as they are very inflammable. No light should be anywhere near them, or on the same table while being used. Now shake up vigorously the bottle of flour and ether, and then allow it to settle. Arrange a paper filter in a funnel, and pour carefully into it the clear ether from the top. Arrange a clean dish (evaporating basin) to receive the filtered ether. Add some more ether to the flour, and treat as before. Collect all the ether after filtering in the dish, and place it for some time in the open air. The ether evaporates quickly, and will leave behind a small drop of oily or fatty matter. This is the natural fat of the flour, which contains from about 0.2 to 0.6 per cent. of that substance. Fats are bodies which stand high in nutritive value; they belong to what are called heat-producers, that is to say, they go when eaten to produce warmth in the human body. One objection to the presence of natural fat in flour is its tendency to become rancid; to this reference will again be made. Fat is a body consisting of carbon, hydrogen, and oxygen.

53. Soluble Constituents.—To examine these proceed in the following manner: In a large flask or bottle place 8 ozs. of flour, and add 20 ozs. (one pint) of cold water; shake up vigorously several times during half an hour. Then let the bottle stand without being disturbed for about twelve hours. There will then be a clear layer of liquid on the top. Pour this off carefully into a filter-paper arranged in a funnel, and collect the clear liquid. This liquid contains in solution the soluble parts of the flour. Place some of this solution in a clean glass vessel—a chemist's beaker answers best. This is in shape very like a tumbler, but being made of very thin glass will not break on being heated. Put the beaker to stand in a vessel of boiling water, after the fashion of a carpenter's glue pot or a *bain-marie.* As the solution gets hot you will notice flakes of a peculiar white substance forming—flakes which look like those formed in hot water in which some white of egg has been spilled. These flakes consist, in fact, of a substance of the same composition as the white of egg, and which, like it, coagulates or becomes solid on being heated. After some ten minutes, filter the solution ; the solid substance remaining on the filter-paper is vegetable albumen. Preserve it on the filter for experiment. Return the clear solution or filtrate to the evaporating basin, and drive off the moisture by placing it on a steam bath. One of these may be made for the occasion by simply resting the basin on the top of a small saucepan containing boiling water. Be sure to keep the saucepan from boiling dry by adding more water from time to time. After some time most of the water will be driven off, and there will remain a thick syrupy mass at the bottom. Taste a small portion of this, and notice that it is slightly sweet. Feel it between the fingers, and notice that it is sticky. Fasten two pieces of paper with it, and notice that they adhere firmly when dry. In this manner we have detected a substance of the nature of sugar, and another of gum-like character.

Evaporate the remainder of this solution to dryness, and then heat a portion in the platinum dish ; a small quantity of white ash remains, which principally consists of potassium —phosphate.

54. Insoluble Constituents.—Make up a little flour, say about an ounce, into dough ; mix it very thoroughly, and let it be moderately stiff. For this purpose a strong spring American flour is the most convenient. Mould the dough into a round lump, and place it in a cup of cold water ; allow it to remain for about an hour. Meantime procure a bowl of clean water. At the end of the hour take the dough in the perfectly clean hands, and wash it carefully in the water moulding it gently between the fingers. The water is soon turned milky, and the dough changes in appearance, becoming more greyish in colour and altering in character. Continue the washing, taking care not to lose any of the fragments of dough, until the washing water does not appear to get any milkier. Now, set the bowl of washing water aside, and continue washing the remains of the dough under a slow stream of running water, working it gently with the fingers all the time. By this time all that remains of the dough is an elastic, yellowish-grey mass. Pull it between the fingers, and notice that in its properties generally it closely resembles soft indiarubber. This substance is that known as gluten. Mould about half of it into a small ball, and set it aside ; it gradually becomes partly transparent, and dries into a hard, horny mass.

In the next place let us turn our attention to the bowl of washing water. This should be allowed to stand for at least twelve hours ; by that time the water will have become clear. Gently pour away as much of the clear water as possible. Then have in readiness a piece of clean calico, say about a yard, folded up until it is about 6in. square. Pour the chalky-looking sediment from the washing water on to the calico, and cover it over. The calico soon soaks up most of the water from the sediment. Let it stand for a day or two in a warm, dry, clean place, at a temperature of about 80° F. By that time it will have become dry, and very little pressure will suffice to break down the cake into a clean, white powder. This substance is that known as starch. Reserve this for future experiments.

As a result of this series of experiments, we have succeeded in obtaining from the flour the following constituents :

Partly soluble—Ash, principally potassium phosphate.

Soluble	Sugar, maltose, Gum, dextrin,	Compounds of C, H, and O.
	Albuminous matter.	Compounds of C. H, O, N, and S.
Insoluble	Gluten	
	Starch, a compound of C, H, and O.	
	Fat, a compound of C, H, and O.	

Of these bodies, the ash and fat have already been sufficiently described. An account of the others follows. To the list might be added cellulose, the essential constituent of woody fibre, which is present in flour in very small quantity, but which it is scarcely necessary for the student to endeavour to separate.

55. The Carbo-hydrates.—This name is applied to the group of chemical substances to which sugar, dextrin, starch, and cellulose belong. They are thus named because they consist of a certain number of atoms of carbon combined with hydrogen and oxygen in the proportions in which they occur in water, that is to say, two atoms of hydrogen for every one of oxygen. The following are the simplest possible formulæ of some of the more important carbo-hydrates :

Cellulose	$C_6 H_{10}O_5$.
Starch	$C_6 H_{10}O$,
Dextrin	$C_6 H_{10}O_5$.
Maltose	$C_{12} H_{22}O_{11}$.
Cane Sugar	$C_{12} H_{22}O_{11}$.
Milk Sugar	$C_{12} H_{22}O_{11}$.
Glucose, or Grape Sugar ...	$C_6 H_{12}O_6$.

It will be noticed that the formulæ of several of these are identical, and all are closely allied.

56. Cellulose, $C_6H_{10}O_5$.—While a little cellulose is found in flour, a good deal more occurs in bran. It differs very much in appearance, according to source from which obtained. Cotton wool is one form of pure cellulose. Cellulose is insoluble in water, dilute acids or alkalies, and most ordinary chemical solutions. It is, in consequence, indigestible, and has no value as an article of food.

57. Starch, $C_6H_{10}O_5$.—This substance forms by far the larger part of flour, and so is of great importance. Starch is also found in other seeds, as barley, rice, &c. ; in potatoes and many other articles of food. The starch of the whole of these has the same chemical composition.

58. Microscopic Appearance of Starch.—When starch is looked at under the microscope it is seen to be composed of very small round or other shaped grains. The source of the starch can often be decided by the shape and size of the grains in the sample being examined. The fortunate possessor of a microscope should make the following experiments. In Chapter VI. a short description is given of how to use the instrument, but such instruction should be supplemented by that obtained from other and larger works. Also, either the instrument-maker from whom the microscope has been purchased, or a teacher, will practically demonstrate how the instrument is to be used.

Take a small quantity of the starch previously prepared from flour, and mix it with water until just milky. Take a drop of this fluid, and place it on a clean microscopic glass slide; carefully drop on it a clean cover, and gently press it down. Soak up any excess of liquid with a little piece of clean blotting paper. Fix the slide on the stage of the microscope, and examine first with the inch and then with the $\frac{1}{4}$ or $\frac{1}{8}$ in. objective. The wheat starch cells are seen to be fairly round or slightly oval. In the accompanying figure they are sketched, together with those of starch, from other sources. In common with many other microscopic sketches given in this book, they are exact copies of sketches from a student's note-book.

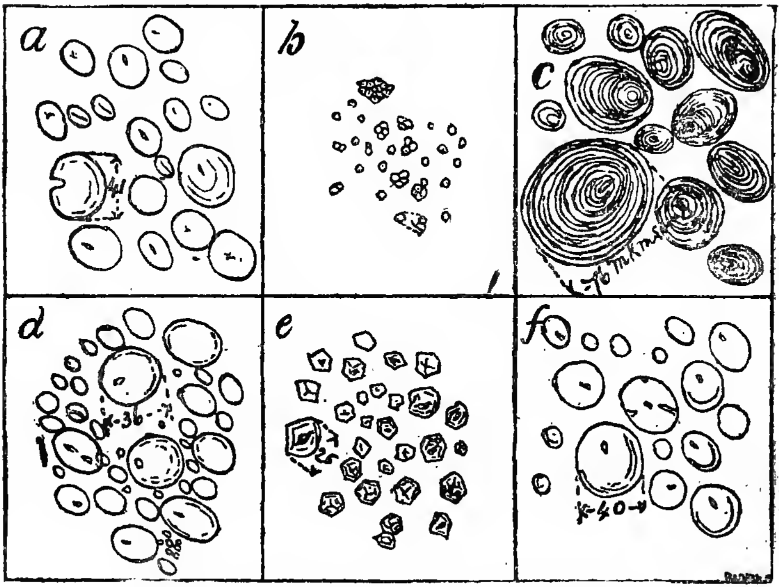


Fig 5.—Microscopic Sketches of Various Starches—87 diameters.
a, Barley; *b*, Rice · *c*, Potato; *d*, Wheat; *e*, Maize; *f*, Rye;

Prepare a little starch from the flour of the other grains by enclosing a little of the flour in muslin and washing the starch out into the water. Grate a little potato, and extract in just the same way. Examine the various starches under the microscope, comparing their relative sizes and shapes.

Below is appended a table of the microscopic characters of the various starches.

Wheat.—The grains are extremely variable in size, diameter being from 0.00009 to 0.0019 in. Medium size granules are comparatively absent. The grains are circular, or nearly so, being sometimes somewhat flattened. Concentric rings are only seen with difficulty; the hilum is not very distinct. In old samples of wheat or flour the starch granules show cracks and fissures. This applies more or less to all starches.

The "hilum" is a sort of nucleus or spot, which is the centre around which the concentric rings of the starch are arranged.

Barley.—Granules more uniform than wheat, and somewhat smaller, average diameter, 0.00073 in.; shape slightly more oval than wheat.

Rye.—Diameter of granules from 0.00009 to 0.00148 in.; average size rather higher than wheat.

Oats.—Diameter of granules from 0.00017 to 0.00118 in.; angular in outline, varying from three to six sided.

Maize.—Average diameter, 0.00074 in.; usual shape, six-sided; corners more or less rounded.

Rice.—Diameter, 0.0002 to 0.0003 in.; shape angular, three to six-sided.

Potatoes.—Diameter of granules, 0.0024 to 0.0039 in. Larger grains are oyster or mussel shaped; the hilum and concentric rings very distinct.

The particulars of these starches have been given somewhat fully, because adulteration of flour by other grains is generally detected by searching the suspected sample with the microscope for these starches.

59. Chemical Properties of Starch.—Starch granules do not dissolve in cold water, but on being subjected to the action of boiling water a great change occurs. Each grain of starch is made up of an external coating of very delicate cellulose filled within with what may be called starch proper. On treatment with hot water, the starch in the interior swells up and bursts the envelope. The liberated starch then dissolves in the water, and forms a thick, gelatinous liquid, which on cooling solidifies into a jelly. This thickening of starch at the moment of solution is often called gelatinisation. The actual temperature at which starch gelatinises lies between 131° F. (55° C.) and 153°F. (67° C.) for the different kinds of starch.

A solution of pure starch is without taste or smell. Its most remarkable property is that of turning to a deep blue on the addition of a very small quantity of iodine. This test is so important that it must be described somewhat more in detail. Tincture of iodine may be made by dissolving a fragment of iodine in some methylated spirit ; the colour of the solution should be of a fairly deep sherry tint. Whatever solution is being tested for iodine should be either neutral to litmus paper or slightly acid. The reaction does not occur when the solution is alkaline. Prepare some solution of starch by first making into a paste with cold water, and then adding hot water until it thickens. Dilute this down with cold water, and add a few drops of tincture of iodine. The starch at once turns a deep blue. Heat the liquid gently to the boiling point, and this colour disappears ; again cool it, and the colour returns. The presence of water is necessary for this test ; for if the tincture be added direct to dry flour, it only stains it yellow. If the flour is first wetted, the whole of the starch turns such a deep blue as to be almost black as soon as treated with iodine. It will be seen from this that not only a solution of starch, but also the starch grains themselves, are coloured by iodine in the presence of water.

60. Saccharification of Starch.—One most important chemical change which starch undergoes may be examined in the following manner : Take some stiff starch paste at a temperature of about 140° F., and add to it some dry malt flour—about one-sixth of the weight of the starch used in making the paste. Stir in the malt flour, and notice that the paste soon becomes much thinner, and at the same time acquires an intense sweet taste.

Repeat the experiment in a somewhat different form by simply taking some crushed malt, and first treating a small quantity with water and a little tincture of iodine ; notice the characteristic blue colour due to starch. Next add to 4 ozs. of the malt, in a glass flask or other clean vessel, a pint of water at 160° F., and maintain as nearly as possible at that temperature by standing the flask in a saucepan of water kept also at about 150-160° F. Stir the malt from time to time, and take out a few drops of the mixture, and test by adding to them a drop or two of iodine tincture. This may be very conveniently done on a clean white plate. At first the mixture will be stained full blue; but after a time this disappears, and there is only a reddish-brown colouration. If the experiment is sufficiently prolonged, this also at last disappears. At the same time the liquid becomes much sweeter. From this pair of experiments we learn that when treated in this manner malt converts starch into sugar; not only its own starch, but also starch paste to which it has been added.

The nature of this chemical change is shown in the following equation:

$$\underset{\text{Starch.}}{C_{12}\times_{10}H_{20}\times_{10}O_{10}\times_{10}}+\underset{\text{Water.}}{8H_2O}=\underset{\text{Dextrin.}}{C_{12}\times_{2}H_{20}\times_{2}O_{10}\times_{2}}+\underset{\text{Maltose.}}{8C_{12}H_{12}O_{11}}.$$

Referring back to the list of formulæ given at the commencement of this chapter, it will be noticed that starch is represented by $C_6H_{10}O_5$ as its simplest possible forumla; but careful examination of starch seems to show that it is better to double this formula into $C_{12}H_{2}\ O_{10}$, and then to assume that the molecule contains at least ten of these groups. This is what is indicated in the formula given above. Well, when starch is subjected to such an action as that described in our experiment, the starch is broken up by one of these $C_{12}H_{20}O_{10}$ groups being forced to combine with a molecule of water, and then to form a molecule of maltose thus

$$\underset{\text{Part of Starch Molecule.}}{C_{12}H_{20}O_{10}}+\underset{\text{Water.}}{H_{20}}=\underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}.$$

The remaining nine parts of the starch molecule then constitute a molecule of dextrin. But the malt action still goes on, and successive groups of $C_{12}H_{20}O_{10}$ are detached, and by combination with water are transformed into maltose, leaving behind a dextrin of simple constitution. This may be made to go on until the whole of the starch is thus converted into maltose; but ordinarily the action stops when eight of these groups have been thus changed into maltose, and two of them remain together as dextrin. These formulæ may very likely seem long to the beginner; but it is thought that they show most clearly the nature of the change by which starch is changed into dextrin and maltose, and the relation which these three bodies bear to each other. Sugar is sometimes called *saccharum*, or saccharine matter, hence the term "saccharification," which is applied to this change which starch thus undergoes.

A number of substances are capable of effecting this change on starch. Among them are the dilute acids, as dilute hydrochloric, sulphuric, and oxalic acids. These, however, not only change starch into maltose, but they also further change maltose into another variety of sugar called glucose or grape sugar. This change is expressed thus:

$$\underset{\text{Maltose.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_{20}} = \underset{\text{Glucose.}}{{}_{2}C_{6}H_{12}O_{6}}.$$

Here, again, it will be noticed that the chemical change is one of the addition of water. These actions are sometimes termed, because of this, the *hydrolysis* of starch, and the substances which produce them "hydrolytics," or hydrolysing agents. The glucose used in cheap confectionery, &c., is made from starch in this manner by the action of acids.

We come next to another most important group of hydrolysing agents. These are all of organic origin, some being derived from vegetable, and others from animal, sources. To this class belong the solutions obtained by shaking with water and then filtering the following substances: yeast, flour, bran, and malt; to these may be added human saliva. Careful examination has shown that this active property of these bodies is due in every case to the nitrogenous compounds (that is, compounds containing nitrogen) which these substances contain. The active agents present which possess this property have been in certain cases separated, and have received the following names:

Substance.	Hydrolysing Constituent.
Human Saliva.	Ptyalin.
Yeast.	Zymase.
Flour, Bran.	Cerealin.
Malt.	Diastase.

Of all these bodies diastase has been studied the most carefully. Diastase cannot change starch further than into dextrin and maltose; it is this agent which, of course, has been at work in our experiments with malt and starch. Zymase can change both maltose and cane sugar into glucose. The nature and properties of diastase will be explained more fully in a subsequent chapter.

We will next turn our attention to the products of the saccharification of starch.

61. Dextrin, or British Gum, $C_6H_{10}O_5$.—A small quantity of dextrin is found in wheat and flour; it has, when pure, neither colour, taste, nor odour. It possesses properties very similar to those of gum-arabic, and is largely used for coating paper, &c., in order to make these adhesive. As will be gathered from the explanations before given, there are several modifications of dextrin; the more complicated ones give a reddish-brown colour with iodine.

62. Maltose, or Malt Sugar, $C_{12}H_{22}O_{11}$.—This compound is the most important constituent of malt extract, of which substance it amounts to about from 60 to 65 per cent. when in the solid state. In common with the other sugars, maltose has a sweet taste; it is not, however, so sweet as is cane sugar. Maltose exists in both wheat and flour, and in company with dextrin is formed when starch is acted on by diastase or similar bodies. As before mentioned, maltose is very similar in composition to starch, being formed from that substance by its combination with the elements hydrogen and oxygen in the proportions in which they exist in water. Malt extract (diastase) is incapable of further changing maltose, but zymase converts it into glucose.

63. Cane Sugar, $C_{12}H_{22}O_{11}$.—Cane sugar is very closely allied to maltose, but although it has the same formula, is not identical with it. Cane sugar is not only found in the juices of the sugar-cane, but also in certain roots, as beet-root. Cane sugar is more readily changed into glucose than is maltose, malt diastase being capable of effecting this change. When heated to about 210 C. cane sugar darkens in colour. watery vapour is evolved, and a substance remains behind which is no longer sweet, but which imparts a rich brown tint to water. This is termed caramel. Dextrin and starch form similar bodies when heated.

64. Milk Sugar, $C_{12}H_{22}O_{11}$.—This body has the same formula as cane sugar, and is found in milk to the extent of about 4 or 5 per cent.

65. Glucose, or Grape Sugar, $C_6H_{12}O_6$.—This form of sugar has received its name because it is present in the juice of ripe grapes; it also occurs in many other fruits. It is likewise found in the urine of persons suffering from diabetes. This body is of interest to the baker as being the ultimate form to which all sugars are changed by the action of hydrolytics, or diastasic agents. Glucose is not so sweet to the taste as cane-sugar. Several varieties of glucose are known.

66. Albuminous Matters.—These are a most important class of substances, and differ from the carbo-hydrates by their containing, in addition to carbon, hydrogen, and oxygen, the elements nitrogen and sulphur as essential constituents. They have also received the names *albuminoids* or *proteids* and from their nutritive properties are frequently termed flesh-formers. Albuminoids are obtained both from animal and vegetable sources. Thus albumin, from which the name of the group is derived, exists dissolved in water in the white of egg; the same substance occurs in such vegetable substances as flour. The composition of the different albuminoids varies somewhat. The following is the result of an analysis of a sample of egg albumin, which may be taken as a type of the group:

Carbon	53.3	per cent.
Hydrogen	7.1	,,
Nitrogen	15.8	,,
Oxygen	22.1	,,
Sulphur	1.8	,,
	100.1	

From these numbers the following has been calculated as the simplest possible formula for albumin: $C_{72}H_{112}N_{18}O_{22}S$. The actual molecule is probably a multiple of this containing most likely several of these groups.

We have at present simply to deal with those albumin compounds which exist in flour; a portion of these, as we have seen, are soluble, while the greater part do not dissolve in water, but constitute an elastic mass, called gluten, when separated by the action of washing from the remainder of the dough.

67. Soluble Albuminoids.—On heating an aqueous (that is, watery) infusion of flour, we have already seen that solid flakes are produced by the solidification, or coagulation of the albumin present; in addition to this there is another albuminoid present to which the name of legumin is given. This is also found largely in peas and beans. The albuminoids are distinguished by their very great tendency to putrefy or become rotten, especially in the moist condition. When they do so, the sulphur is changed into sulphuretted hydrogen, the well-known gas having the smell of rotten eggs. The soluble albuminoids are not distributed equally throughout the whole wheat grain, but are found particularly in the germ and the inner layer of the bran.

The soluble albuminoids of flour, particularly those from the bran and germ, possess the remarkable property before described of changing gelatinised starch into dextrin and maltose. The act of germination, or starting to grow, considerably increases this actvity of the albuminoids, hence changes of the starch are found to a great extent in flour from "sprouted" wheat.

68. Insoluble Albuminoids, Gluten.—The gluten, which has been washed out of flour in a previous experiment, is one of the most important bodies which it contains. Gluten is practically insoluble in water, and, as seen, is exceedingly tough and elastic. The quantity and quality vary with different kinds of flours. Gluten in small quantities dries off at ordinary temperatures into a hard, horny mass, which may be kept indefinitely without undergoing any change. But if the gluten be in masses of considerable size, or confined so as to retain the water within it, it gradually softens, breaks down into a creamy mass, and evolves a most disgusting odour of putridity. It is the gluten of flour which gives dough its great elasticity, and which confines the gas within it during the time the sponge or dough is working.

69. Malt.—This substance is so largely used by bakers that some description of it is necessary. In order to prepare malt, barley is taken, damped, and allowed to grow. At a certain stage the grain is removed to a kiln, and there heated sufficiently to kill the growth. It has been already mentioned in passing that with the act of germination the soluble albuminoids of wheat acquire, to a considerable extent, the power of acting on starch. This is especially the case with barley, and, accordingly, the malt thus produced contains soluble albuminoids in a most active condition. On heating crushed malt together with water, not only is the starch of the malt converted into dextrin and maltose, but so is that of any other raw grain, such as maize or rice, which may be mixed with it.

70. Diastase.—This is the name applied to the active albuminoid principle of malt by which the saccharification of starch is caused. This body can be extracted in a very concentrated form from malt by first mixing with cold water, allowing it to stand, and filtering until bright. The liquid thus obtained contains diastase in solution ; by proper chemical means the diastase itself can be separated as a white powder. A thousand pounds of malt only contains about 2 lbs. of diastase, but 1 lb of diastase can convert about 2000 lbs. of starch. Recent experiments on malt seem to show that diastase is not exactly a separate and distinct substance, but rather a property which certain portions of the soluble albuminoids possess in a high degree.

CHAPTER IV.

FERMENTATION.

71. Meaning of Term.—If the brewer takes, at a blood-heat, some of the sweet liquid, or wort, which he gets by treating malt with hot water, and adds to it some of the scum (which the brewer calls "yeast") of a former brewing, it is soon found that a vigorous action proceeds. The wort loses its sweet taste, and what is of importance, throws up to its surface much more yeast than was originally added to it. While this is going on the mass looks as though it were boiling, and hence the name fermentation, which is derived from the Latin word meaning "to boil." Every baker further knows that if he mixes some of this yeast with the water with which he makes dough, the dough itself rises or ferments, and becomes through its whole mass filled with small holes.

72. Nature of Yeast.—It was at one time supposed that the peculiar change in brewers' wort referred to in the last paragraph was simply one of decay ; but in opposition to this view was the fact that fermentation was always accompanied by the growth of this yeast substance. It was not till the invention and use of the microscope that the actual nature of yeast was discovered. If a little yeast be taken and thinned down with water until just milky, and then looked at under a moderately high power (an eighth objective), it will be found to consist of a number of little round or oval cells. An outer thin envelope is noticed containing a fluid mass in the interior. These little cells are, each of them, a minute form of plant life. It is true that they are without leaves, stems, or roots, but these are, after all, not absolutely necessary to a plant. Ordinary plants require their roots to descend into the soil, and there forage for their nutriment. Their leaves and stems provide the means by which, from the air, other portions of their food are derived. But yeast is a plant which lives in a solution of its own food, and finding it thus, in immediate contact with it, needs neither roots nor leaves with which to collect it. We must, then, remember that **Yeast is a very simple form of microscopic plant.** Its botanical name is *Saccharomyces cerevisæ*.

73. Definition of Fermentation.—We are now in a position to say somewhat more definitely what fermentation is. We find that the fermentation of wort does not proceed without the presence of yeast, for if a little wort be filtered, and then boiled for some minutes and allowed to cool, it will, provided no air is admitted, remain unaltered for an indefinite time. Further, air even may be admitted, if it be first scrupulously freed from yeast and other similar forms of life. But the addition of the smallest quantity of yeast immediately induces fermentation, and chemical change rapidly proceeds A French chemist, whose name is almost as well known in this country as his own, called Pasteur, says that the chemical action of fermentation is simply an accompaniment of an act of living, beginning and ending with it. Fermentation of brewers' wort (that is, the ordinary type of fermentation) cannot proceed without the growth, development, and multiplication of yeast cells, or the continued life of yeast cells already formed. The albuminoids have been already spoken of as bodies exceedingly likely to putrefy, but this putrefaction can only proceed in the presence of certain living organisms. In their absolute absence it is impossible to induce putrefaction ; while with their introduction putrefaction at once sets in. It will be gathered from this that there are various kinds of fermentation. Not only is there the particular series of changes produced by the action of yeast on wort, but there are also the souring of milk, the change of wine into vinegar, and the changes of putrefaction, all of them due to the action of minute organisms. **The term "fermentation" is consequently applied to that group of chemical changes which are produced as a result**

of, and are inseparable from, the life and development of minute miscroscopic organisms.

74. Alcoholic Fermentation.—This is the name given to the ordinary fermentation process of the brewer and baker, because alcohol is produced as one of the principal products. Let us view this first of all as a chemical change, and then also learn something of the nature and growth of the yeast plant. Strictly speaking, glucose is the only substance capable of alcoholic fermentation; secondarily, any of the sugars may be fermented, which, by the action of the zymase of yeast or other body possessing similar properties, can be changed to glucose. In the simplest possible form, the following is the chemical change which occurs:

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

Alcohol is very well known as the substance called spirits of wine; it is the basis of all spiritous liquors, as brandy, whisky, &c. Carbon dioxide gas is described in the first chapter of this book. Beside these bodies, a small portion of the glucose is changed into glycerin and succinic acid, but with these we need not trouble. The following experiment shows very clearly the changes produced by fermentation: Take about 1 lb of crushed malt, and mix it with two quarts of water at 160° F.; set it in a warm place, so as to keep it as nearly as possible at this temperature for an hour and a half; stir it occasionally during that time. Next filter off the clear, sweet liquid from the top, and cool it rapidly to a temperature of 70° F. At this stage, if possible take the gravity or density—that is, find out the weight of a given volume of the liquid. This may be easily done by means of a hydrometer, which instrument may be purchased for about eightpence. One should be selected registering single degrees from 1000 to 1040. Failing the hydrometer, a rough substitute can be made in the following manner: Take a sound bottle cork, and stick in one end of it a strip of wood about 8 in. long and the stoutness of a match. Now stick nails in the lower end until the cork sinks in cold water until only just the top of the stick is above the surface. Float either this or the hydrometer in the malt wort, and note the position it takes; it will float much higher than in the water. Now, the heavier a liquid is, the lighter does a body float in it, so that this wort is bulk for bulk heavier than water. Notice, also, that it is somewhat syrupy in appearance and consistency. Next pour the wort in a large glass flask ; add to it half an ounce of compressed yeast broken down in a little of the wort itself ; have fitted to the flask a cork and glass leading tube, stand the flask in a warm place, and place the end of the leading tube in a glass vessel of lime-water. After a short time bubbles of gas will be seen arising from the liquid, and the lime-water will become milky. In this way we have proof of carbon dioxide gas being formed. The action should now be allowed to proceed until no more gas is evolved. On examination it will be seen that the quantity of yeast has visibly increased. Taste the liquid ; it has no longer a sweet taste. Try again its density with either the hydrometer or the prepared substitute ; the liquid is lighter, and consequently the hydrometer sinks farther than before. Notice, also, that it is thinner and not so syrupy. Take out a little of the yeast, and set it on one side. To complete the experiment, the following addition should, if possiple, be made : Attach the leading tube of the flask to a Liebig's condenser (this is an instrument by which steam is condensed to a liquid by passage through a tube enclosed in a jacket containing cold water and then collected), place a light under the flask, and as the liquid boils collect the first few drops of liquid which escape from the condenser, say about a teaspoonful. Notice that this has a strong smell of siprits, and also that it has a hot, fiery taste. Place a light to it ; it burns with a light-blue flame. These are all characteristics of alcohol.

75. Microscopic Appearance of Yeast.—Let us now see what yeast looks like when examined under the microscope. For this purpose at least an eighth objective is required. Take first of all a very little of the compressed yeast broken down into a milky fluid with water, mount it on a slide in the same manner as was described in paragraph 58 for starch, and examine it. The cells are either single or at most grouped together in couples. The interior of each cell is filled with matter having a granular structure, and their outline is firm and well defined. There can usually be distinguished a comparatively empty spot within the cell ; this is called a "vacuole," and is due to the jelly-like matter in the interior shrinking together and leaving a vacancy. When this yeast is sown in malt wort, the cells swell somewhat and grow more transparent; the vacuole disappears, and as the growth proceeds a small bulging is noticed at one end of the cell. This is a bud, and gradually it grows more prominent, until after a while a sort of neck is formed between the bud and the parent cell. This gets gradually smaller, until it finally closes entirely, and the daughter cell is entirely separate and distinct from the parent. This process of budding continues until large groups of cells are formed, budding in all directions from each other. All these new cells are more transparent than the old ones; in fact, the parent cell can frequently be distinguished in the centre of the group, and is recognised by its darker outline. During the course of the experiment mentioned in the previous paragraph a little of the liquid should be taken out and examined microscopically at intervals; the act of budding, together with the other changes described, may then be noticed.

In the following figure are represented brewers' yeast and also continental distillers' compressed yeast:

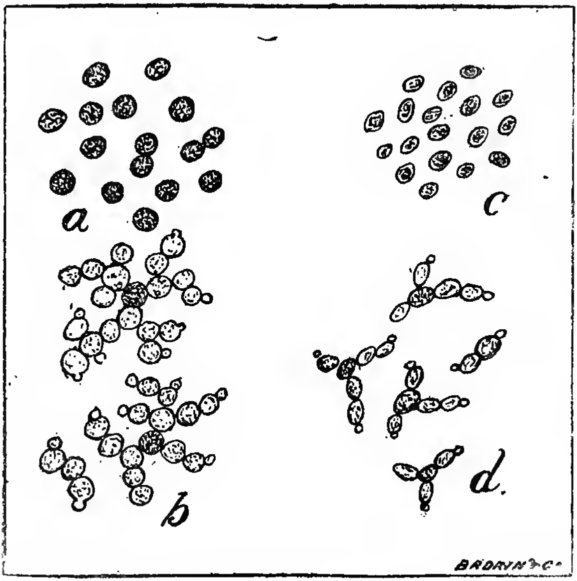


FIG. [illegible].—YEAST.
a, Brewers' yeast at rest; *b* ditto actively budding; *c*. Distillers' yeast at rest: *d*, ditto actively budding.

We will give another drawing of yeast, showing not only budding, but also the reproduction of yeast by means of the formation of internal seeds or spores :

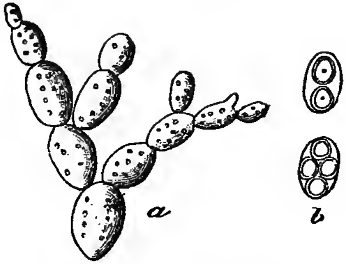


FIG. 7.—YEAST. Drawn by Lûrsen.
a, Bud colouring ; *b*, two spore-forming cells.

As the new yeast produced by fermentation matures, the cells acquire a firmer outline, and their contents become more granular.

In much the same way as there are different kinds of wheat or potatoes, so there are different kinds of yeast. Brewers yeast is one well-marked variety, and the continental yeast's another. Different kinds of potato vary in flavour ; so, too, do the beers brewed by different yeasts. There is no doubt that the actual variety of yeast has a very great deal to do with the flavour of bread.

76. Chemical Composition of Yeast.—The following is the result of careful analysis of a sample of yeast :

Nitrogenous or Albuminoid matter ...	62.73
Cellulose (envelopes)	22.37
Fatty matter	2.10
Mineral matters	5.80

It will be observed from this that albuminoid matters form the principal part of yeast. The mineral matter or ash of yeast is of great importance, and, as the result of careful analysis, is found to consist almost entirely of phosphates, as shown below :

Potassium phosphates, KH_2PO_4 ...	81.6
Magnesium phosphate, $Mg_3(PO_4)_2$ ...	16.8
Calcium phosphate, $Ca_3(PO_4)_2$ ...	2.3

The ash of yeast is very similar in composition to that of wheat.

77. Substances Necessary for the Nourishment of Yeast.—Yeast requires for its proper growth and development the following substances :

Sugar.—Obtained as glucose, or indirectly by the transformation of starch, maltose, &c.

Nitrogenous matters.—Obtained either from ammoniacal salts, or preferably from certain organic nitrogenous substances.

Mineral matters.—Supplied usually by the mineral matter of the grain, which produces the medium in which the yeast is grown.

Of all these bodies sugar is the one of first and paramount importance. In fact, **it is absolutely necessary that sugar be present ; for if we abstracted, by any means, from wort or dough all the sugar contained in it (and also all substances capable, by the addition of yeast to flour, of being converted into sugar), without touching the other constituents, the addition of yeast would produce no gas. Everything would remain quiet until the moment when signs of a more or less advanced putrefaction showed themselves.** Yeast, on being sown, in pure sugar and water, sets up fermentation, but in the absence of sugar no fermentation can occur.

As yeast contains such a large amount of nitrogenous matter, it will readily be understood that some source of nitrogen is necessary for its healthy development. Yeast can obtain its nitrogen from ammonium nitrate, which is a substance of inorganic origin, but much more easily and conveniently from certain organic bodies. Albumin itself is unfitted for the nourishment of yeast, but certain nitrogenous substances called peptones are well suited for supplying nourishment to yeast. The peptones are bodies formed by the partial digestion of albuminoids. It is the presence of peptone-like bodies in malt wort, &c., which causes these substances to be so thoroughly adapted for yeast growth and development. Yeast required for bakers' purposes especially needs to have been grown in liquids containing ample quantities of suitable nitrogenous matter. A striking illustration of this is found in the fact that brewers' yeast obtained from those breweries where sugar is used in large quantities, to the comparative exclusion of malt, is weak and unfitted for bread-making purposes.

Among the different mineral substances required by yeast potassium phosphate is the most important. This body is absolutely necessary for yeast growth and development. Magnesia, also, is of great service, if not indispensable, for healthy yeast growth. In many cases where yeast action is proceeding slowly, it is due to lack of sufficient mineral nourishment: if this be supplied the growth proceeds much more rapidly and healthily.

It will, then, be understood that the absence of either class of nutritive matter acts prejudiciously to the healthy growth and action of yeast.

78. Action of Oxygen on Yeast.—The splitting up of sugar into alcohol, carbon-dioxide, glycerin, and other bodies is more or less a respiratory action. That is, its object is the procuring of oxygen, wihch is required by the yeast plant. It is this capacity of thus decomposing sugar for respiratory or breathing purposes which distinguishes yeast and makes it so useful to the baker. But although we can make yeast breathe (or acquire its oxygen) in this way, by submerging it in a solution containing sugar, yet, after all, this is not the easiest mode of breathing for yeast. Like other members of the fungus family, to which class of vegetable bodies yeast belongs, yeast can grow and derive its necessary oxygen from the air. Now, this second must be looked on as the normal or simplest condition of yeast growth. Under such circumstances it would lead a life in which it absorbed oxygen from the air, and returned the equivalent quantity of carbon dioxide. When yeast is submerged in a sugar solution, containing also free oxygen, the oxygen is *first* used up, and *afterwards* the sugar is attacked. Further, of these two conditions of yeast life, the fresh-air one is the easiest, and the vital powers of the yeast plant are much less exhausted by living in air than by growing and developing in sugar solution. As a consequence of this, yeast which is comparatively exhausted by prolonged fermentative action is greatly strengthened and invigorated by once more breathing free oxygen. It will readily be understood that it is easier to get oxygen from air where it is in the uncombined state than from sugar, in which it is in a state of combination. I have before now made use of an illustration which may again be of service here. A working diver, as is well-known, has to perform his duties at the bottom of the sea, and has air conveyed down to him by tubes. Breathing is difficult under these conditions, and sooner or later the diver returns to the surface to rest. During this time he is somewhat like the yeast breathing in air, his work at the bottom being stationary. Yet it, on the whole, profits, for his fresh air braces him up and strengthens him, and when he again resumes work it is with increased vigour and energy. So, too, yeast may be submerged, and doing the work of fermentation until its action becomes sluggish through exhaustion. The fermenting liquid is now thoroughly stirred so as to bring air in contact with every part; fermentation ceases until the air is all used up, but the yeast then re-starts fermentation with increased vigour. **The admission of free oxygen, under suitable conditions, is a great stimulant to yeast growth, development, and work.**

79. Substances Unfavourable to Yeast Action.—There are certain substances which act as poisons to yeast; in small quantities they retard, and in larger quantities altogether arrest, fermentation. Among these are the mineral acids, except phosphoric acid; oil of lemon, mustard, and turpentine; carbolic acid, salicylic acid; excessive quantities of sugar and alcoholic solutions when over 20 per cent. in strength. One of the most important substances belonging to this class is common salt, which exerts a considerable retarding influence on fermentation.

80. Effect of Temperature on Fermentation.—Yeast growth and action proceeds most rapidly between the temperatures of 25° and 35° C. (77° and 95° F.). Below 25° C. yeast grows, but not so rapidly; while with a temperature so low as 9° C. (49.6° F.), the action of the yeast cell is arrested until the temperature is once more raised. With an increase of temperature over 35° C. the action of yeast is weakened; and when in the moist state, it is destroyed by a temperature of about 60° C. (140° F.). The act of fermentation causes a rise in the temperature of the liquid being fermented. For reasons to be subsequently described, it is advisable for manufacturing purposes to conduct fermentation at a lower temperature than 25° C.

81. Other Forms of Fermentation.—In addition to the chemical changes produced by yeast, there are others also caused by minute living organisms. The majority of these lie outside our present subject, but some few are most important to the baker. To these attention must be briefly directed. They include the following: putrefactive, lactic, ropy or viscous, and butyric fermentation.

82. Putrefactive Fermentation.—This change takes place particularly in substances of albuminoid composition. These bodies are first of all changed into compounds, having a most putrid or rotten odour, and, finally, by oxidation into inorganic substances. The chemical changes are somewhat intricate, and apparently the various stages are conducted by different species of organisms. That essentially termed the ferment of putrefaction is known by the scientific name of *Bacterium Termo*. A little clear maltwort, or flour infusion, on being exposed to the air, soon becomes turbid, and then is found, on microscopic examination, to be crowded with *bacteria*, as seen in the following figure, No. 8:

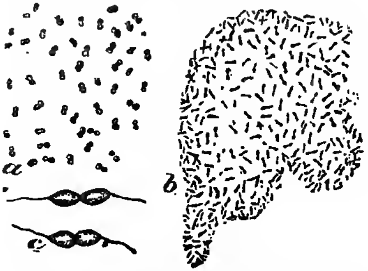


FIG. 8.—BACTERIUM TERMO.
a, Isolated cells; *b*, Grouped cells—650 diameters.
c, Ditto, 4000 diameters.

82a. Lactic Fermentation.—This is the fermentation by means of which milk turns sour. It also undoubtedly occurs, under certain circumstances, in bread. Sugar of milk forms a special glucose in just the same way as maltose and cane-sugar form glucoses. Glucose, when subjected to the action of the lactic ferment, undergoes the following decomposition:

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Lactic Acid.}}{2HC_3H_5O_3}.$$

The organism which produces lactic fermentation is called *Bacterium Lactis*, and is shown in the following sketch, figure 9.

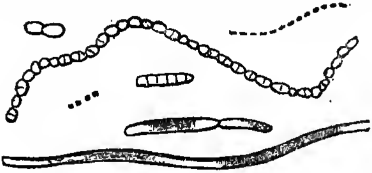


FIG. 9.—BACTERIUM LACTIS—1140 diameters.

This organism is always found on the surface of malt. and in more or less quantity in most commercial yeasts. Lactic fermentation proceeds under very much the same conditions as ordinary alcoholic fermentation, so that when yeast contains the lactic organism, the production of lactic acid very easily follows. A more dilute sugar solution than that used for yeast growth is specially suited for the action of lactic ferment. Comparatively speaking, this organism is not endowed with such vigour as is yeast; in consequence, a temperature which only slightly retards yeast action practically arrests that of the lactic ferment; so, too, small quantities of salt, and other bodies which retard yeast growth, prevent, to a very much greater extent, the generation of lactic acid. The bitter principle of hops has a powerful retarding action on lactic fermentation. It will be seen from this that it is possible to select conditions which shall almost entirely prevent the action of the lactic ferment, while only slightly hindering that of yeast. These conditions are, working at a fairly low temperature, say from 65° F. to 70° F., with, in malt wort, some hops present, and with salt in dough. A very vigorous yeast of itself lessens the danger of either beer or bread becoming sour during fermentation.

83. Butyric Fermentation.—This is allied to lactic fermentation. Butyric acid is one of the substances produced when butter becomes rancid, hence the name "butyric." Butyric fermentation is a change which occurs in lactic acid, being produced by an organism called *Bacillus subtilis*, which organism is shown in figure 10.

The following is the change which occurs :

$$\underset{\text{Lactic Acid.}}{2HC_3H_5O_3} = \underset{\text{Butyric Acid.}}{HC_4H_7O_2} + \underset{\text{Carbon Dioxide.}}{2CO_2} + \underset{\text{Hydrogen.}}{2H_2}.$$

It follows from this that the production of butyric acid is a step which follows after the production of lactic acid. Like lactic fermentation, the production of butyric acid is favoured by an unduly high temperature and restricted by a low temperature, and the presence of such substances as salt and hops.

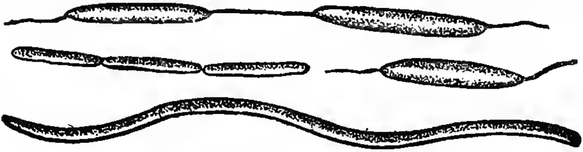


FIG. 10.—BACILLUS SUBTILIS—4000 diameters.

84. Production of Acetic Acid.—Wine and beer are liable, under certain circumstances, to change into vinegar. This change consists of a combination of alcohol with oxygen :

$$\underset{\text{Alcohol.}}{C_2H_5HO} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Acetic Acid}}{HC_2H_3O_2} + \underset{\text{Water}}{H_2O}$$

The production of acetic acid is effected by an organism which grows as a mould on the surface of the liquid. This body acts by conveying oxygen to the alcohol, an action decidedly opposite to that of the yeast organism, which extracts oxygen from the bodies subjected to its influence. This film of mould is often termed "mother of vinegar" and beer or patent yeast on which this or allied substances have formed, is said to have become "mothery."

CHAPTER V.

PRACTICAL BREAD-MAKING OPERATIONS.

84a. Principles of Practical Work.—We have now worked through a description of the principal laws of Chemistry, Heat, and Fermentation which have a bearing on practical bakery work. A description has also been given of the baker's raw materials, and the changes to which they are subject. Our next task is to follow carefully the various operations necessary to make a loaf of bread, and to trace out the application of these principles to their successful performance. In doing this we will commence at the very beginning with the making of patent yeast. It must be remembered that the details of bread-making methods vary in different parts of the country, but the *principles* are the same throughout. The methods described will not exactly coincide in all particulars with those adopted by each individual reader, but the intelligent baker will find no difficulty in accommodating the descriptions to his own modes of working, and in grasping the principles it is intended to convey.

85. Patent Yeast Brewing.—We will give a thoroughly trustworthy recipe for the manufacture of patent yeast, with directions for its use. At the same time, an effort will be made to explain the reasons for each step, and the precautions to be taken in order to obtain the greatest degree of success.

Utensils required. One or more tubs of convenient size, which should be about the same depth as width across.

Vessels for boiling or otherwise heating water. Strainer.

Good copper-cased thermometer; also hydrometer and jar for same.

Materials required: Hops, crushed malt, hot water, old or store yeast.

In the first place, all vessels must be scrupulously clean. They must be thoroughly scalded after use with boiling water, or still better, covered over and a jet of live steam led into them for some minutes by means of an indiarubber pipe leading from a steam boiler. They must not be closed up while not in use, but must be left so that the fresh air has free access to them. The object of such care in keeping everything clean is to prevent any lodgment of lactic or other objectionable ferments in the crevices of the vessels. These ferments are often spoken of as "disease germs," because they produce what to the baker is a diseased or unhealthy form of fermentation.

We will now start to make our yeast. The quantities given can be increased or diminished in the same proportions for more or less yeast if required. The first operation consists in boiling together some water and hops. This may be done in a clean iron vessel, but iron, especially if the slightest degree rusty, is apt to discolour the liquid. Clean copper or enamelled iron vessels are most suitable for this purpose. Where a jet of clean steam from a boiler is obtainable, that forms a most convenient mode of heating the water, as it can be used in the ordinary ferment tub.

Suppose, first, that you intend to boil the hops over a fire. Then take ½ ℔ of hops and 7 gallons of water. Boil these together for half an hour, the copper or other vessel being kept covered. By this time the water will have boiled down to about 6½ gallons. Pour the whole direct into a tub of about 18 gallons capacity.

In the second place, let us take the alternative in which the water is heated by steam. In paragraph 41 it is pointed out that to raise 10 gallons of water from 60° F. to the boiling point about 1½ gallons of water in the form of steam are required, producing together 11½ gallons. If to produce 11½ gallons of boiling water, 10 gallons of cold water are necessary then in order to obtain 6½ gallons of boiling water, about 5½ gallons of cold water are required. This is a result obtained by a calculation in proportion. Place, then, in the tub 5½ gallons of cold water together with the hops, pass in a jet of steam from the boiler, and continue it till the water boils; then turn it almost off, until a gentle current bubbles through the water, which allow to continue for half an hour. At the end of that time there will again be about 6½ gallons of a boiled decoction of hops.

Whichever way produced, make the 6½ gallons up to 10 gallons by the addition of cold water. A calculation such as is described in paragraph 35 will show that this mixture will have a temperature of about 160° F. (71° C.). (To get the right quantity it is a good plan to have a little gauging staff for each tub. This should be marked off in gallons, once for all, by filling the tub with water by means of a gallon measure, and cutting a notch on the staff showing how high the water stands for each gallon.) The quantity should be made up to as nearly as possible the same in each case. Before adding the last gallon of water test the temperature with the thermometer and add a little warm, instead of cold water, if necessary, at the last. The object of taking the quantities given is to obtain finally 10 gallons of water at 160° F. with the boiled hops. This method of working prevents the necessity of waiting for the water to cool, or the taking of any steps for the purpose of cooling it. As has been previously explained, the object of hops in the yeast is to prevent any souring or other diseased fermentation being set up.

Now, the next step is mashing the malt : Weigh off 16 lbs. of the crushed malt and stir it in with water and hops, thoroughly breaking down all lumps. Cover the tub over, and place where it will not readily cool. In about three quarters of an hour test with the thermometer ; if the temperature has fallen below 140° F. (60° C.) add a little boiling water, *stirring rapidly all the time*, so as to bring the temperature up to that point. Let the mash stand altogether about an hour and a half. Then just test it in the following manner : take out two or three drops on the end of a glass rod and put them on a white plate ; add a single drop of tincture of iodine, and note whether any blue colour is being produced. There should neither be any blue colour, from unaltered starch, nor any but a trace of reddish-brown, from the presence of the higher dextrins. If any blue is still seen the mashing should be allowed to proceed a little longer. The presence of unaltered starch may be due either to an error in the temperature or to the use of bad malt. The reason why this temperature is selected is that it is one which is well suited for the conversion of the starch of the malt into sugar. With too low a temperature the change does not proceed so rapidly, and with too high a temperature the diastase of the malt is destroyed. Boiling water, therefore, must not be used to extract the malt. Further, the mashing of the malt must not be arrested too soon. Not only is there danger of some of the starch remaining unchanged, but also the baker not only wants to change his starch, but, in addition, he requires to convert the greater part of it into maltose, because dextrin is of no particular service to him. The nature of this series of chemical changes is described in paragraph 60.

Next, the mixture must be strained from the one tub to another. This should be done through a tin strainer such as is sold by the bakers' tool-makers for the purpose. Squeeze the grains which remain on the strainer as dry as possible then wash them by adding cold water in small quantities, and again squeezing as much as possible of the liquid from the grains. Altogether there should thus be obtained rather over 10 gallons of bright wort. Next, take the density of the wort, by means of the hydrometer, for description of which refer back to paragraph 74. Now, the more malt that has been used to the water the denser the wort should be, and the higher in it the hydrometer will stand. Supposing that altogether 10 gallons of wort have been obtained from the 16 lbs. of malt, the wort ought to have a density of 1038; at least, that is the density which the Excise expects the brewer to obtain from his malt. With the comparatively imperfect appliances which the baker has at his disposal, he can scarcely expect to get the full extract, but certainly, as a matter of practice, he ought to get nothing less than 1030. It is a good plan always to get the density of the wort at the same point before starting fermentation, and for this purpose 1030 is a good standard to work at. If the density is found uniformly too low, then the proportion of malt used should be increased; if too high, more water must be added. The necessary quantity of water may be easily calculated in the following way: The volume of wort is in inverse proportion to the density after subtracting 1000. Thus, supposing the 10 gallons of wort have a density of 1035;

then as 30 : 35 : : 10 : $11\frac{1}{2}$ gallons.

the wort will have to be made up to $11\frac{1}{2}$ gallons, that is, $1\frac{1}{2}$ gallons of water must be added.

Now, in the next place, for the temperature at which fermentation is to be commenced. The addition of cold water will have lowered the temperature of the wort, but it is very desirable that it be brought down to the fermenting temperature as rapidly as possible. The reason of this is that the temperature of 95° F. to 104° F. (35 to 40° C.) is that at which there is most risk of diseased fermentation occurring; therefore it is highly desirable to get the wort cooled below this point as rapidly as possible. Undoubtedly, the most convenient method of effecting this is by means of a small Laurence's refrigerator, which are now made in suitable sizes. This consists of a series of pipes through which cold water is passed, so arranged that the liquid to be cooled can be poured in a stream down the outside. Having such a refrigerator, place the tub of wort underneath and dip some up with a gallon measure, and pour it down the refrigerator; test the temperature and repeat this sufficiently often to reduce it to from 65° F. to 70° F. (18 to 21° C.). In summer the lower temperature may be taken; in winter the higher. The pouring over the refrigerator not only cools the wort, but also serves the purpose of aerating it ; this will be understood from the description given in paragraph 78 on the action of oxygen on yeast. In the absence of the refrigerator the cooling of the wort may be hastened by floating in the tub a clean zinc pail filled with cold water. It will be remembered that water is best cooled by the application of cold to the upper surface if the wort is cooled in this way it should be aerated by vigorous stirring, or else pouring from tub to tub two or three times. As a result of these operations, we now have well aerated wort at a temperature of from 65° to 70°F. The next step is the fermentation.

In order to induce fermentation a small quantity, say a quart, of yeast may be added, which has been preserved from the last brewing, or an ounce of fresh, healthy, compressed yeast may be employed. During fermentation the wort should be kept at as uniform a temperature as possible, neither being allowed to get too hot nor too cold. In summer time, particularly, there is a tendency for a rapid rise in temperature to set in. This may conveniently be controlled by use of the pail of cold water before referred to, by means of which it should be brought back to about 68°F. During fermentation allow the yeast to be freely exposed to the air,

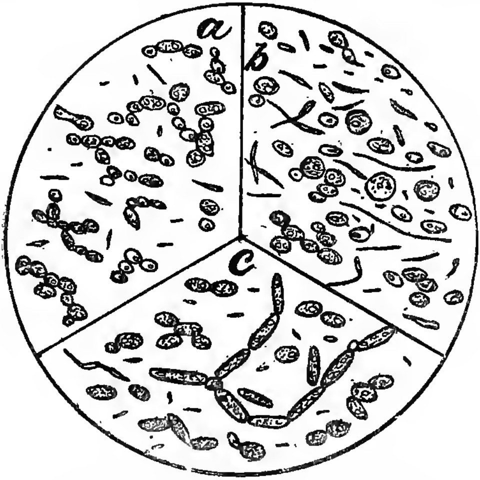


Fig. 11.—Bakers' Patent Yeast—440 diameters.

and if at any time the fermentation is sluggish, stir it thoroughly so as to aerate the wort. In twenty-four hours the yeast should be ready for use, but will be in better condition at the end of two days. As fermentation proceeds the density will be found to become less if the liquid is tested by the hydrometer. When the yeast is made, keep it thoroughly exposed to the air. The quantities of malt and hops recommended here are in excess of those often used, but the strength of yeast is governed not only by the quantity of water but by the malt employed. The smaller quantity of the strong yeast will go farther than the larger quantity of the more dilute yeast. There is no saving of malt in making a very watery yeast, but there is the very serious objection that through insufficient nutriment the yeast is weak and feeble; and, further, as has been explained, a dilute infusion of malt is a much more favourable medium for acid fermentation. Figure 11 is a sketch of different specimens of bakers' yeast.

The sketch marked *a* is from a yeast of very good quality, brewed in a rich wort; *b* is one which was much poorer—the yeast cells are transparent and unhealthy-looking, while disease ferments are present in far too great quantity. The sketch *c* was drawn from a sample of store yeast which had been kept tightly corked in a bottle. Notice in this the peculiar chains of elongated cells.

86. Virgin Yeast.—Instead of setting the yeast by the addition of previously made yeast, the wort is sometimes allowed to stand until fermentation sets in spontaneously. Yeast prepared in this way is termed "virgin yeast." Under these circumstances fermentation is started by yeast cells carried into the yeast by the air. The method is, however, somewhat uncertain; at times a vessel of yeast altogether escapes being impregnated by yeast finding its way into it, and goes putrid. Value is attached to this method of setting yeast, as thereby a yeast is obtained which, in the opinion of some bakers, produces bread of a specially good flavour.

87. Scotch Flour Barms.—These represent another method of brewing or preparing yeast, used principally in Scotland and some parts of Ireland. The great difference is in the use of flour as a substitute for most of the malt. The following recipe for the production of flour barm is condensed from a description by Thoms which originally appeared in *The American Miller* :—

Utensils and Materials required.—A 30-gallon tub, small tub for malt-mashing ; 10 lbs. malt ; 3 ozs. hops, and a jar to infuse them ; about 40 lbs. flour, one-third of which should be spring American, the remainder Talavera or sound home winter flour ; 2 or 3 ozs. salt ; 8 or 12 ozs. sugar ; and about 18 gallons of boiling water.

First mash the malt for an hour and a half in 3 gallons of water at 160°F. This operation has the same object as the mashing previously described in malt yeast making. Great care must be taken that the water is at no higher temperature than 160°F., otherwise the diastasic power of the malt will be weakened or destroyed. At the same time, pour a gallon of boiling water over the hops and allow it to stand. Strain both the malt and hop liquors into the barm tub, and wash the malt grains with another gallon of water, at say, 200°F. The liquor in the tub will now have a temperature of from 140° to 145°F. Next thoroughly mix in the flour with the hands. This mixture has next to be scalded. For this purpose about 7 gallons of boiling water are added, the whole being sharply and continuously stirred with a stick. Begin by adding two gallons of water, stirring well up ; then add 3 gallons more, and again stir ; finish with another two gallons, and more stirring. The object of this process is to gelatinise the starch of the flour, taking care that at the same time the temperature does not rise sufficiently high to destroy the diastase of the malt. In this way a thick, jellyish paste is obtained, of which there is about 12 gallons.

The tub and its contents are now left in the barm-house uncovered for twenty-one hours or thereabouts. During this time the gelatinised starch of the flour is changed into dextrin and maltose ; the barm acquires a sweet taste, and becomes much thinner. After some hours it becomes distinctly sharp to the taste, and acid. It is next poured from tub to tub in order to thoroughly aerate the mixture. By this time it will have cooled down to about 84°F. When this stage is arrived at, add the salt and sugar, and also a handful of raw flour. Place the tub where its contents will maintain a temperature of about from 80°F. to 84°F., keeping it either uncovered or very ghtly covered. This operation may be performed probably twenty-four hours after commencing to brew. During the next twenty-four hours give the barm two or three stirrings, and at the end of the time again aerate it by pouring from tub to tub. The number of times which this is stirred will depend on the degree of vigour of the fermentation, which should during this time have commenced. If somewhat sluggish, stirring should be resorted to the more frequently. At the end of twelve hours (sixty hours from the commencement) stir up again. The yeast should then be in a state of vigorous fermentation, and will rise and fall. On the third day after brewing the yeast should have completely fallen and be at rest. This barm can now be immediately used, but is much better on the fourth or fifth day after brewing. It will be noticed that this also is a "virgin," or spontaneously-fermented yeast. In the same way as with virgin malt and hop yeast, the fermentation is due to the introduction of yeast cells from the air or surroundings. The opinion is advanced by some that the yeast is, under these circumstances, a direct product of a change in the albuminous portion of the flour. This is not, however, the generally-received view of the matter by the great majority of scientists who have given the subject their attention. When the whole operation is conducted on the small scale in chemically-clean glass vessels, the author has never thus succeeded in obtaining alcoholic fermentation and yeast growth.

In addition to virgin barm, there is another variety of flour barm known as Parisian barm. The only difference is that when the mixture has cooled down to about 84°F., instead of putting in salt, sugar, and flour, and letting it self-ferment, it is "pitched" or "set" by adding in winter 1½ gallons of old barm or virgin, and in summer 1 gallon. Active fermentation is now over in about from sixteen to twenty-four hours, when the tub is removed to a cooler place, and should be allowed to remain some twenty-four hours before being used. In these flour barms it will be noticed that not only are no steps taken to prevent the development of lactic acid fermentation, but that means are taken to encourage it. It is the verdict of Scotch bakers that flour barms brewed so as to prevent the formation of lactic acid are inferior to those in which that acid is present.

Observe that in the brewing of these barms every arrangement is made for the access of oxygen from the air in abundance. In yeast brewing the principal object is not the fermentation of the saccharine matter present, but the growth and development of yeast. This is much assisted by the presence of free oxygen, which directly stimulates the growth of yeast. It is a great mistake to keep yeast during the time of fermentation carefully covered over and protected from the air. The object, undoubtedly, is to prevent its being chilled. This should, however, be provided for by keeping the fermenting tub in a sufficiently warm place.

88. Brewers' Yeasts.—These were at one time much more largely used for bread-making than they are now. The mode of manufacture does not differ greatly from that employed by the baker to make patent yeast. The great difference is that the baker allows his yeast to remain in the liquid in which it was brewed, stirring the whole together before using it. The brewer skims off the yeast as it rises to the surface of the liquid, which, remaining behind, constitutes the beer.

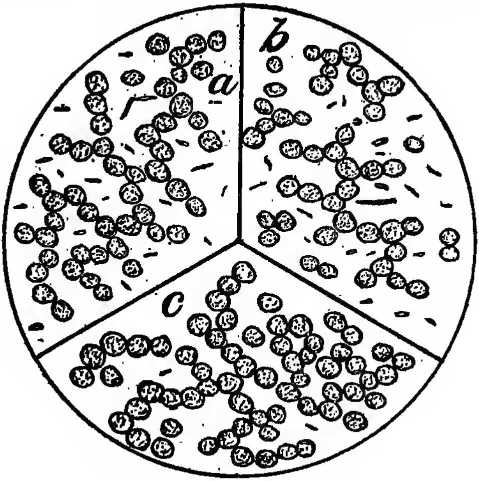


FIG. 12.—BREWERS' YEAST—440 diameters.

Brewers' yeast has a bitter flavour from the hops which have been used in its manufacture; the colour itself is also dark.

Of recent years, since the abolition of the malt tax, brewers have been at liberty to use any form of sugar for brewing purposes. The result has been that the yeast, having been grown in a medium containing less suitable nitrogenous matter than does a wort made entirely from malt and hops is weaker and less energetic as an agent for the fermentation of bread than were the older brewers' yeasts. Still, brewers' yeast, when healthy and of good quality, is well adapted for bread-making. Bread made from brewers' yeast is somewhat dark coloured, and if too much is used, rather bitter. Its action is slow, and the bread is usually small, and at times has a foxy crust; but it is very rarely sour if reasonable care is taken in working with it. Brewers' yeast, when well made, should be free from disease ferments. In figure 12 a view of various brewers' yeasts is given.

Samples *a* and *b* were taken from samples of yeast, as supplied by London brewers' yeast merchants; sample *c* was obtained direct from the brewer. It has the appearance of being a healthier and purer yeast, and in working shows itself possessed of much better qualities.

89 Compressed Yeasts.—Every year is making these better known to bakers. The greater portion of yeast of this

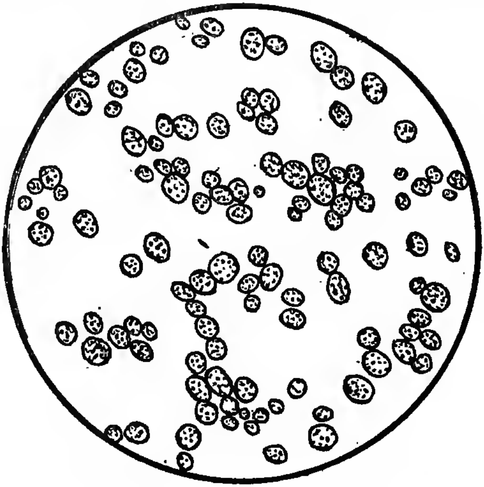


FIG. 13.—CONTINENTAL COMPRESSED YEAST—440 diameters.

description now being used comes from the Continent, where fermentation is carried on, on the large scale, as a preliminary to the distilling of spirits. These yeasts are imported from France, the Netherlands, and Germany. The distillers make a mash from malt mixed with a certain proportion of raw grain, as degermed maize, rye, &c. This wort is somewhat similar to that used for the manufacture of Scotch flour barms, and is well adapted for the growth of a healthy, vigorous yeast well suited for bakers' purposes. Distillers compressed yeasts are now being manufactured with success in this country; also brewers' yeasts are being washed, compressed, and put in the market in that form for bakers. The merits or demerits of these latter will depend largely on the quality of the yeast before being compressed.

The better class of compressed yeasts are very free from disease germs; field after field may often be examined under the microscope without showing any signs of lactic or other foreign organisms. Figure 13 is drawn from a sample of Continental compressed yeast.

This yield contained but one foreign ferment; the cells were firm and healthy in appearance, and their interior was very distinctly granulated. The compressed yeasts produce a good coloured, bold-looking loaf, with no tendency to foxiness in the crust. The flavour is good, but not so distinctive as that of either bakers' patent or brewers' yeast. These yeasts are exceedingly strong and vigorous in action; but are liable, when too much is used or they are allowed to overwork, to yield sour, or incipiently sour bread. There is more risk in this respect with compressed distillers' than with ordinary brewers' yeasts: the hops in the latter are undoubtedly a preservative against sourness.

One recent cause of complaint against compressed yeast is their adulteration with starch. This is added before the compression, in order to allow the yeast to be obtained more readily freed from the large amount of water it contains. In summer time, particularly, absolutely pure yeast does not, as a rule, keep so well as the same yeast with a small percentage of starch added. So far, the addition is most decidedly not an adulteration; it is an addition not to the prejudice but to the decided advantage of the baker. It adds to the keeping properties of the yeast without detracting from its fermentative power. In fact, the addition of starch may quite possibly result in a pound of yeast containing actually more pure yeast than it would without such addition of starch. This may seem a paradox, but yet a little thought will make it clear. Commercial compressed yeast consists of yeast cells and water, together with starch in most samples. The added starch, within certain limits, takes the place not of some of the yeast, but of the water; so that while the pure yeast consists of a certain proportion of yeast cells together with water, the mixture may contain a higher proportion of yeast cells, with a less proportion of water and starch taken together. This fact is in many cases borne out by actual analyses, and also by tests of the gas-evolving power of the yeasts. This applies only to what may be termed legitimate additions of starch, which should not exceed 15 per cent. When, as in some cases, as much as from 30 to 40 per cent. has been added, the addition is fraudulent, and well merits punishment under the Adulteration Act. The addition of starch is readily detected by means of the microscope, or by the addition of tincture of iodine to a little of the yeast broken down in water.

90. Potato Ferments.—At one time potatoes were much more largely used in bread-making than at the present time. Formerly boiled potatoes were added direct to the dough, and were employed as a direct substitute for flour. This practice is forbidden by law, except the bread be stamped and sold as a mixture, and not as made from pure wheaten flour. In the form of a ferment potatoes are still, however, largely employed, but their use even in this form is much less extensive than formerly. The reason probably is that many bakers feel that the necessary extra trouble and expense involved in their use is not compensated by any corresponding advantages possessed by potato ferments. Much will depend on the locality and the kind of bread demanded. One point should be clearly understood: the use of potatoes for the purpose of yeast-making and development, as in a ferment, is not in any sense an adulterant, and is definitely permitted by law. As before said, opinions are divided as to whether the advantages repay the extra expense and trouble. Potato ferments tend to make bread moister and sweeter in flavour; they also somewhat darken the colour. Other things being equal, they enlarge the size of the loaf ; but also, at the same time, increase the risk of the bread becoming sour. The advantages of potato ferments are seen most strikingly when either the yeast or the flour is weak. Either of these causes produce low, small bread which shows a decided tendency to run when placed in the oven. By stimulating the growth and development of yeast, they enable it to hold up the loaf much better even though the dough be weak and devoid of elasticity. Ferments are especially suited to use with brewers' rather than compressed yeast. The stimulant of the ferment gives the brewers' yeast that strength which it lacks, while at the same time there is a decided safeguard in the non-liability of brewers' yeast to turn sour. Compressed yeast is to a much greater extent independent of such aid, and its introduction is undoubtedly one cause of the less frequent use of ferments.

In making a ferment some 5 to 12 lbs. of potatoes are taken per sack of 280 lbs. of flour. These must first of all be thoroughly washed, an operation which is best performed by a good type of washing machine. **Too much importance cannot be attached to the absolute removal of all dirt.** Not only are dirty potatoes repugnant, but their effect is serious on the colour of the bread. It is a mistake to select the very lowest price potatoes to be obtained ; if worth using at all, a good quality should be selected. The potatoes must next be cooked, and may be either boiled or steamed, preferably the latter. All tubs used for ferments must be perfectly clean, and should be scalded out or thoroughly steamed on each occasion after use. The potatoes may be next transferred to the tub and mashed by means of a potato-masher. Water is then added so as to bring the temperature down to about 80°F., and the volume up to about 2 gallons more or less. About 2 lbs. of raw flour are then added, and the whole is stirred up well so as to aerate it. A good plan is to pour the ferment from tub to tub. The yeast is next added, and well stirred. The quantity varies from about 1 to 2½ lbs. of brewers' yeast. The ferment tub should be allowed to stand in a moderately warm place, and if there is no danger of chilling is preferably uncovered. Fresh air is a most valuable aid to all yeast growth and fermentation. In a time varying from three to six hours, the ferment will have risen and again fallen to a state of rest. It is now ready for use, and while it may, without danger, be permitted to stand for some time, provided it is kept in a cool place, it is as well to arrange to have it ready just when wanted. The ferment is strained previous to being used for the next stage of bread-making. If the ferments be taken too soon, the yeast is immature, and the after fermentation is deficient in vigour. As a consequence, pinched, heavy bread is produced.

When desired, potato ferments may be set with patent malt and hop yeast; the method of working is very much the same as has just been described. Compressed yeast may also be employed if wished; in this case from 4 to 6 ozs. per sack will be found sufficient. The ferment should be set at rather a lower temperature, and should not be allowed to stand about after it has fallen. Compressed yeast ferments are in greater danger of turning sour than those made with brewers' yeast.

Let us next examine a little the nature of the effects produced by a ferment. About three-quarters of the weight of a potato consists of water; there is about 15 per cent. of starch, 2.5 per cent. of nitrogenous matter, and the rest made up of dextrin and other substances. The act of boiling gelatinises the starch of the potato. The nitrogenous substances present are of a kind particularly adapted to the growth and development of yeast. The yeast and the soluble albuminoids of the raw flour between them effect, to a limited extent, the conversion of the starch into dextrin and maltose. The maltose serves as a saccharine medium in which the yeast grows and produces; further, the soluble nitrogenous matter of the potato acts as an energetic yeast stimulant.

It seems probable that the ferment may exert some beneficial influence on the yeast in another way. There is a great difference in the character of a malt wort and a dough as substances in which yeast has to grow. The former contains an abundance of sugar, and being a liquid, offers every facility for fermentation: the latter contains sugar in but small quantity, and from its semi-solid condition does not lend itself readily to the growth and development of yeast. Hence it is that brewers' yeast transferred direct to a dough is something like causing a hot-house plant to at once have to bear the rigours of winter. The setting a brewers' yeast in a ferment gives it a sort of intermediate hardening in a liquid thicker than wort, but thinner than dough; while at the same time it has the stimulating action of the food substances present. In scientific terms, a sudden change of environment or surroundings may destroy an organism: a gradual change enables the organism to accommodate itself to the changes in its environment. One possible reason why distillers' yeast is so much more vigorous in dough than brewers' yeast seems to be that it is grown and developed in a medium containing large quantities of material similar in character to raw flour.

91. Doughing Operations.—Having the yeast in a state of readiness, whether with or without having undergone the preliminary process of working with a ferment, the next step in bread-making is the mixing of the yeast with the requisite flour and water. At the outset we are here confronted with the complications arising from the division of the making of the dough in two stages, namely, those termed by the baker sponging and doughing. We will for the moment pass over this, and deal with the simpler though less common method of working where off-hand doughs are made; that is, doughs in which all the flour, yeast and salt are mixed together and kneaded in one operation. Let us glance at the changes which then occur. The first one to happen to the flour is that the gluten combines with water and forms the tough and elastic mass which distinguishes wheaten flour dough from a dough of rice flour or oatmeal. The flour contains, in addition, sugar, starch, and soluble albuminous bodies. The yeast consists principally of *saccharomyces*, or the yeast-plant; but there are also present various forms of *bacteria*, not only associated with the yeast, but also with the flour. The temperature being suitable, alcoholic fermentation soon sets in, and the sugar of the dough is decomposed into carbon dioxide gas and alcohol. Owing to the action of the gluten the gas escapes but slowly from the dough, and gradually distends it, thus causing the dough to rise. Although yeast is capable of performing its vital acts of living and breathing in dough, there does not seem to be sufficient nutriment present to permit growth or reproduction. On the contrary, the yeast present at the outset gradually disappears. Not only does the yeast act on the sugar, but it also attacks the albuminoids present. The soluble portion of these albuminoids is first changed into a more active condition; and in this form they more or less attack the starch, according to its degree of soundness, converting it into dextrin and maltose. The gluten is also acted on, gradually becoming softer and more elastic ; but if the gluten be devoid of much tenacity to start with, or the process of fermentation be carried too far, this elasticity is in great part lost. The dough becomes "short." The albuminoids are by this action changed more or less into peptones—those bodies described as being a step farther forward in the direction of digestion. It will be seen, then, that one most important function of yeast is the conversion of the albuminous matter of flour into a form specially adapted for use as human food, owing to its ready digestibility. We have, then, during doughing, the following changes going on : **Alcoholic fermentation of the sugar, softening and partial peptonising of the albuminoids, and a limited change of the starch by the altered albuminoids.**

Unless fermentation be allowed to proceed sufficiently far, the dough will produce a bread which is pinched in appearance and raw in flavour. If the fermentation proceeds too far, the bread is flavourless, short, and crumby in texture,through the elasticity of the gluten being destroyed, and possibly even sour. There is practically but little guide to the judgment in determining when dough made in this manner is ready for the oven beyond that gained from experience from day to day working with it under the same conditions.

92. Sponges and Doughs.—The greater number of bakers make first of all a sponge with the yeast, water, and part of the flour, and afterward mix in with the sponge the remainder of the water, flour, and the salt, thus forming a "dough." The reasons for this division seem lost in obscurity, but possibly one of the causes which led bakers to adopt this method of working was the difficulty of, at one operation, kneading the whole of the flour and water together into dough. Dough of the necessary stiffness would be most difficult to handle. But, as is well known, after lying for a time dough becomes much softer and easier to work. If the baker then mixed a part of this flour and water, together with his yeast, and allowed the mixture to stand for some hours, that portion of the flour would have become much softer, and the labour of then mixing in more flour and water would be less than if the whole of the dough had been made off-hand. Or, on the other hand, there may have been some baker, more thoughtful than his fellows, who tried the experiment of making a batch with a sponge and dough instead of off-hand. He would have found that by the double process he obtained a bolder loaf, and thus the division into sponging and doughing may have been invented. But there are other very good reasons which justify this subdivision of dough-making into two stages. The sponge is almost always made much slacker than the finished dough; as a result of this, the yeast works in it much easier than it does if the dough were stiff. With the sugar and nitrogenous matter of the flour in a more liquid condition, the yeast obtains its nutriment more easily, and the gas formed by fermentation is not held in so tightly. The yeast, in fact, does not require to use so much effort in order to throw off its products of respiration. All these more favourable conditions enable the yeast to work with better advantage. It seems possible that even growth and reproduction may proceed during the sponge stage; at any rate, the yeast is enabled at least to retain much more of its pristine vigour. One most important result of this is that less of it can be used. Where some 6 to 8 ozs. of yeast are sufficient to the sack when a sponge is used, something like 20 ozs. are employed per sack for an off-hand dough. This applies, of course, to doughs made from the same kinds of flour, and, as nearly as possible, in the same way in each case.

Another important advantage of the sponge and dough method is that it permits the selection of different flours for each of the two operations. This leads us to the question of classification of flours according to their properties, and the principles involved in flour blending. As in practical work these matters must be considered and dealt with before the making of either sponges or doughs, the present will be an appropriate place in which to deal with these matters.

93. Classification of Flours.—Although the student is already acquainted with the nature of the constituents of flour, but little has been said as to the proportions of each present in flour of different kinds. Not only the scientific, but **the natural classification of flours is according to the wheats from which they are derived.** In addition to this classification, the miller also grades flour from the same wheat according to its quality. Roller-milling, particularly, permits the miller to produce a number of grades of different quality from the same wheat. The highest and most expensive grades are those which are of the best colour. From this they descend to the lowest or darkest grades, called "red dog," and below that into "offal." A straight-grade flour is strictly one which consists of the whole of the flour the wheat yields. These are now but rarely made, and at present the name is applied to a low or medium grade of flour. We have usually some three or four grades of flour which are named in the following order :

First Patent ...	... Best quality.
Second Patent ...	... Second quality.
First Bakers' ...	... Third quality.
Second Bakers'	... Fourth quality.

Flours are also known by a special name or "brand" given to each variety. Thus we have "Pillsbury's Best," a patent ; Washburn's "Iron Duke," a bakers' flour ; and so on. Many British millers adopt a purely empiric classification, and sell their flours under such names as Superfines, Whites, and Households. These names are supposed to indicate certain grades of flour, but give no indication of the actual nature of the flour or the variety of the wheat. Some home millers also sell their flour under fancy names or brands.

In the following table an endeavour is made not only to give the moisture, gluten, &c., of some of the leading types of flour, but also indicate their general qualities :

NAME.	Moisture.	Dry Gluten.	Water Absorbed. Quarter per Sack.	GENERAL CHARACTERISTICS.
Spring American Patent ..	12.60	13.42	71.0	Hard, dry flours, containing a high proportion of very elastic gluten, which only slowly softens during fermentation. Water-absorbing power high ; colour good, but white, with comparatively little yellow or bloom in the bread. Loaf

NAME.	Moisture.	Dry Gluten.	Water Absorbed. Quarts per Sack.	GENERAL CHARACTERISTICS.
Spring American Patent ..	12.60	13.42	71.0	very bold and of good texture; crust yellow without foxiness; will bear very hot oven. Bread tends somewhat rapidly to become hard and dry, and is comparatively flavourless. *A doughing flour, but it may be used in rapid sponges, or one-third in long sponges.*
Spring American Baker's ..	13.16	14.54	73.0	Also hard and dry, higher proportion of gluten, but usually somewhat less elastic; softens very slowly. Water absorbed rather higher than with the patent; colour dark and greyish, varies with different brands. Loaf bold but textureless, crust very foxy, catches readily in the oven. Bread harsh and dry, has with samples of specially low grade. a strong beany flour. *Straights and Bakers' grades are sponging flours, not good doughing flours.*
Canadian Hard Fyfe Wheat Patent ..	12.90	10.8	82.0	Very much the same characteristics as the spring American patent, but has remarkably high water-absorbing capacity. *A sponging and doughing flour, but neither Straights nor Bakers' grades from this wheat are good doughing flours.*
Winter American Patent ..	11.66	8.26	65.0	Comparatively soft flours, containing a moderate proportion of gluten, which softens more rapidly during fermentation

NAME.	Moisture.	Dry Gluten.	Water Absorbed. Quarts per Sack.	GENERAL CHARACTERISTICS.
Winter American Patent ..	11.66	8.26	65.0	than the preceding, but still is fairly tough and elastic. Absorb medium quantity of water. Colour is very good, white and more bloomy than the spring American. Makes a very good loaf by itself, quite of medium size and fair texture. Good yellow crust without foxiness. Bread fairly moist and pleasant in flavour. *Doughing flours all grades, but may be used for rapid sponges taken on the first turn.*
Winter American Baker's ..	11.73	10.1	69	Similar on the whole to the patents in general properties. Some brands make doughs with little elasticity, but which hold up well and do not give during fermentation. Loaf not up to medium size, low and with rather a tendency to run. Much less foxy crust than spring American of about same grade, also better colour in crumb. Flavour moderate, and usually devoid of any harshness. Bread sometimes clammy. *Doughing flours all grades, but may be used for rapid sponges taken on the first turn.*
Californian Straight Grade	12.1	7.13	64.0	These are usually weak, dry flours, with comparatively little gluten. They are of good colour, full yellow, and sweet in flavour.

Name.	Moisture.	Dry Gluten.	Water Absorbed. Quarts per Sack.	General Characteristics.
Kubanka (Russian) ..	10.90	16.06		Hard dry flour, with unusually high percentage of gluten; makes a big loaf. Colour very yellow, almost pea shade; bakes very foxy. Bread very harsh and coarse in flavour. *Sponging—long sponges — not good doughing flour.*
Azima (Russian) Straight Grade	12.36	12.70	71.5	Hard flours, with good percentage of gluten, but softens more readily during fermentation than spring American grades, for which these flours make useful substitutes. Colour of patents good; rather more tendency to foxiness than the American. Loaf bold, but if the dough is permitted to lie, frequently shows tendency to run. Bread comparatively flavourless; in lower grades coarse in flavour. *Sponging flour; the patent grade may be used one-third in sponge and one-third in dough.*
Hungarian Best Patent ..	10.82	10.48	76.0	Dry and comparatively soft flours; only medium percentage of gluten, which is very soft but elastic. Water-absorbing power remarkably high; colour white, with a most delicate shade of bloomy yellow. Loaf not very large, but of peculiar silky texture; crust yellow, without foxiness. Bread moist and of exquisitely delicate flavour. *Doughing flour, but may be used in rapid sponges taken on the first turn.*

NAME.	Moisture.	Dry Gluten.	Water Absorbed. Quarts per Sack.	GENERAL CHARACTERISTICS.
Hungarian Lower Class Patents	10.98	9.23	74.5	Flours with less gluten and lower water-absorbing power than the higher-class patents. Colour very good, but usually full yellow. Bread moist, and somewhat liable to be clammy.
No. 2 Calcutta Flour ..	12.60	9.68	71.5	Indian flours generally are hard flours of a ricy character. Their gluten is low in amount, and usually very deficient in elasticity. The quantity of water absorbed is high. Colour is low, except with very great milling precautions. Loaf is small and runny, devoid of texture, and foxy. Bread is harsh and beany in flavour. *This is good for neither sponge nor dough.*
Old White English Wheat Flour ..	14.00	9.82	62.0	Flours from English wheats are usually soft and damp. Vary considerably with change of climate and locality. Proportion of gluten low and devoid of much elasticity. Water-absorbing power low. Patent flours are very good colour and bloomy; bakers' grades dark and grey. Loaf small and compact; crust of better class of flours free from foxiness. Bread is moist, and has a very sweet, nutty flavour. *Doughing flour all grades: may be used alone, doughing direct.*

NAME.	Moisture.	Dry Gluten.	Water Absorbed. Quarts per Sack.	GENERAL CHARACTERISTICS.
Flour from Kiln-dried Scotch Wheat ..	13.80	7.94	63.0	Scotch flours are even moister and softer than those from English wheats. Like them they are low in gluten and water-absorbing capacity. Loaf is small, bread moist, and flavour pleasant. *Doughing flour all grades: may be used alone, doughing direct.*

Opinions will naturally somewhat vary as to the relative merits of these different flours according to the standard set up in the particular locality, but the judgment above formed is based on bread made in crusty cottage loaves such as are commonly made in London. By obtaining some baking samples of these and other varieties of flours, any baker can easily construct such a table for himself as is given here.

The moisture and dry gluten in the table are in percentages. The water-absorbing power is in quarts per sack as determined by the author's special instrument for that purpose, the viscometer. It is not meant that each flour will in each case take as much water as is set down against it. The standard taken for comparison is a dough about equal in consistency to that employed to make very slack tin bread The figures simply represent the quarts of water necessary in each case to produce a dough of this degree and stiffness.

Being anxious to make this table as widely useful as possible, the author forwarded proofs of it to Mr. Thoms, of Alyth, Scotland, and also to a gentleman having a wide experience of the Liverpool flour and baking trades. Mr. Thoms appended some remarks to the table itself, which are introduced in italics. In an accompanying letter he states that "the characteristics of the flours you quote agree with my knowledge of them here." Mr. Thoms also made some valuable suggestions as to gluten-testing, to which reference is made in a subsequent chapter.

The following is a condensed copy of the report received from the author's Liverpool authority: I do not agree entirely with your descriptions, and give you the following opinions, which are based upon wide experience in milling and baking in Liverpool, and the distribution of foreign flours over the whole of the United Kingdom, north of Gloucester, Northampton, and Peterboro'. I state this that you may qualify my opinion, and because the grades in London below patents vary so much from the grades imported in the districts just defined.

Spring American Patent.—We considered all the Mineapolis and the Minnesota country mills which used Northern and No. I hard wheat would make patents having a fine yellow bloom ; any shading of this into brown or towards white was a serious defect. The Milwaukee and Chicago millers mixed softer varieties of spring wheat, which gave them whiteness, but less strength, and the flours commanded the trade of the districts for which a fine patent was too yellow and too strong. For the same reason, the hard wheat flours made the crust too foxy, and when winter was not obtainable the bread was sometimes covered with paper in the oven, to prevent the crust becoming too hard and dark. We did not find the bread become hard and dry if a vessel of water were placed in the oven with the bread. If the dough for the bread were made as thin as batter, the loaf would keep moist and good flavour for a week.

Spring Bakers.—Your description, while being exact for the London imports, will not be clearly understood by the trade in other parts, where the term signifies a Straight, or First Bakers. The colour of these is also a bloomy yellow, and the approach of brown or grey is also a most serious defect. The variableness according to brand depends upon the milling, as some millers make what is called a Second Patent and a Second Bakers, whilst others do not make either, and some millers make an almost pure Straight which has the actual "low grade" taken out of it. For the term "Bakers," elsewhere than in the districts supplied by London imports, the texture is so distinct that the loaf has a pile which can be peeled like an onion ; and frequently when it has cooled a few hours, the loaf will be seen covered with curls. The beany flavour is never found in a real Bakers, as it is only the low grade (not quite the Red Dog) which has not been taken out, and flour with that flavour should, without hesitation, be classed as a Second Bakers.

Winter Patent.—Colour more delicate in bloom than Spring Patent, not so rich in yellow.

Californians.—Only occasionally yellow ; are considered to have a whitish-grey colour which is inclined to shade in some grades to chalky-white, and in others to a slightly bluish tint ; but each miller's quality is fairly well known, according to the valley in California in which the wheat was grown. The Oregon, on the other hand (which in this district is frequently called Californian, as all Hungarian flours are called Vienna). has a distinctly yellow colour, with much greater moisture and more flavour. This tone can be obtained at the pleasure of some millers well situated who have the command of the Walla Walla wheats. The Californian and Oregon flours will not pass under one description ; and if attempted the Liverpool baker would quickly make his protest be felt.

Readers will be interested in these criticisms, as explaining the opinions held by purchasers and users of flour in different parts of the country. The author's thanks are due to both these gentlemen for the trouble taken by them in commenting on the proofs of the original table.

94. Flour-Blending.—Flours, then, are obtainable on the market from single wheats, according to the natural classification just referred to. Some of the principal varieties of these have been described. These we may term classified or graded flours. There are also flours produced which are not sold as the product of any particular wheat, but under such names as "Households," or else by fancy names : these unclassified flours, for convenience, shall be termed "ungraded" flours.

Where off-hand doughs are employed, the nature of the blend must depend on the locality and the kind of bread required. Where what is frequently called farm-house bread is made, a large proportion of English may be used, as this bread is required to be sweet, and a large loaf is not looked for. Sufficient strong flour must, however, to taken to give the loaf a fair amount of elasticity. The use of ungraded flours must depend on the price asked for them. They may frequently be obtained cheaper than flours of particular classes, but this cheapness, it must not be forgotten is obtained by the use of low-priced wheats. The flours should be tested, and then judged against the price ; possibly, they may, by cutting down the average price of the mixture, permit of a greater quantity of a more expensive flour being used, and so the whole blend may be improved with no increase in price. No hard-and-fast rule can be laid down. If one mixture does not suit (and it can be made up at first in quantities only sufficient for baking a sample loaf), then use more of the flours which are rich in those properties in which your mixture is deficient. Throughout, however, bear in mind what the effect will be on the cost of your blend.

"FLOUR BLENDING."

We next must consider blending for sponging and doughing purposes. This method of working has the great advantage that the baker has far more control over his flours and the method of using and mixing them. Descriptions shall first be given of mixtures for sponging, and then such as may be used for doughs.

Sponge Mixtures.—For sponging purposes hard wheat flours only should be employed, and that without any admixture of soft flours. Our most serviceable flours for this purpose are those from spring American or hard Russian wheats. Either of these may be used separately, or in conjunction with each other. During the year 1888, good Duluth, or other American spring wheat flours, were obtainable in plenty, but in 1889 they were scarcer and of inferior quality. The result was that they were largely replaced by Russian wheat flours. Russian wheat flours will not, as a rule, bear so long sponging as spring Americans,therefore processes must be modified to suit the flours. While the author recommends the use of hard wheat flours only for this purpose there are others who advocate the admixture of small quantities of soft flours. The basis for this recommendation is that such flours hasten the action of the sponge. This is doubtless caused by the greater quantity of albuminoids in either a soluble, or easily rendered soluble, condition which they contain. Under the influence of yeast these albuminoids acquire active diastasic power, and act not only on the starch, but also soften the gluten. It is very doubtful whether any advantage arises from this treatment. In the entire absence of such flours as those mentioned, others can on an emergency be employed in their stead. One of the best substitutes is a good tough winter American flour, but with this the sponging operation must be shortened considerably. Among flours which should *not* go into sponge are the Indians, or any mixture containing Indian. Although these flours are hard and dry, yet they possess no elasticity; and the sponges, instead of being tough and elastic, are short and "rotten." This word "rotten" is not used in the sense of meaning putrid; but as without strength, just as we say of a piece of rope which is worn out that it is rotten. The sponge is a very risky place in which to use ungraded flours of any kind. If such flours must be bought and used, let it be elsewhere than in sponge.

Of course, the commercial element must enter largely into the question of all these mixtures. For example, a blend of old spring American and new Azimas (at the time of writing) was suggested. At that moment there were being offered in London large parcels of old spring American flours, from one to two years old—bakers' grades. Very good value for many purposes were obtained by mixing these with such flours as new Azima patents. Again, it must be repeated that in mixing flours, the state of the market, and what kinds are relatively cheap, must be considered, as well as the actual properties of each kind of flour.

Dough Mixture.—Here considerable latitude comes in. What is used in the dough has to be considered in conjunction with the sponge mixtures, as the dough flours are the complement or balance of those employed in the sponge. A certain standard of colour is required to be maintained for the bread. The baker must consider whether patent or good-coloured flours can be bought most cheaply from the hard or soft varieties. Suppose that in spring Americans, bakers grades are much cheaper in proportion than patents, while there is comparatively little difference in price between the patents and low grades of such flours as winter Americans and English wheats. Obviously in this case the sponge mixture will consist of the dark-coloured spring American, while whiter flours will be used in the dough. If, for any reason, hard flour patents have been bought exceptionally cheap, then they can be used with darker doughing flours. In this way a standard of colour is maintained. While, however, circumstances may lead to sometimes using dark-coloured sponge with white dough mixtures, or the opposite, it is advisable to keep the two about the same tint, except where some decided advantage results from doing otherwise. The reason for this is that where great difference exists between the colour of sponging and doughing flours, there is a danger of "streaky" bread through insufficient mixing. This danger is reduced to a minimum and practically obviated by the use of a good doughing machine.

We may next come to the question of strength. A certain proportion of tough, strong flour is needed in the dough mixture ; flour of the spring American or Russian types may again be employed here, but not to too great an extent. American winter wheat flours, from their toughness, combined with the property of readily softening in the dough, are well adapted to form the backbone of the dough mixture.

A class of flours well deserving the baker's attention is that obtained from Hungary. These flours, although soft, absorb large quantities of water, and so increase the yield. They confer a splendid bloom on the bread, and also give it a most attractive silky texture when cut, or where close-packed loaves are separated. Their flavour is delicate, and keenly appreciated by lovers of fine white breads.

We have studied colour, strength and texture : last, but not least, comes the question of flavour. Among flours distinguished for the possession of this quality, reference has been already made to Hungarians. For fulness of sweet, nutty flavour there is no flour available in this country equal to that from sound, ripe, English wheats. Hence the importance of this flour as a means of conferring flavour on the mixture.

The proportions used of these various flours must depend on the kind of bread wished to be made, price that can be given for the mixture, and other considerations. When English wheat flours are used, they are at times excessively soft ; under such circumstances they must be balanced by the admixture of greater proportions of the harder varieties.

Those bakers who have a liking for Indian wheat flours are recommended to use them at the dough stage. It is somewhat difficult to recommend what should be done with any ungraded flours which may be used, as their properties vary between such very wide limits. Some are of excellent quality, and may be used largely; others are of low quality, and the only inducement to purchase them is their correspondingly low price. Every parcel of flour of this kind must be judged on its own merits. In assigning to it a value, it should be compared in quality and cost with the average mixture; should the two be identical, evidently they are of the same value. If the ungraded flour is better than the mixture, then its value is determined by the quantity of lower-price flour it will take to bring it down to the average: on the other hand, if not equal to the average, the element to be taken into consideration is how much higher-priced flour is necessary in order to remedy its deficiencies, and bring it up to the quality of the blend in which it is purposed to introduce it. This, compared with its yielding properties, are the elements which will determine the value to be assigned, and whether the flour is a bargain or not at the price asked for it.

Flours should be blended as long as possible before use, especially where, as in dough mixtures, the component parts may differ widely in character.

95. Sponging.—Yeast, or ferment, being ready, and sponging flour mixed, the next operation is that of setting the sponge. The old-fashioned mode of doing this is by hand in the trough, while in many modern bakeries the sponges are set by machine. The quantity of flour used for the sponge varies from about a quarter to two-fifths of the whole amount for sponging and doughing. The quantity of yeast also varies considerably from as little as 4 ozs. to as much as 1½lb. of compressed yeast per sack of flour. The quantity of water taken is usually such as to make the sponge slacker than the dough is made. All these variations are governed by the custom of the locality, the length of time which the sponge lies, and the character of the flour used. Where such wide differences exist it is impossible to do more than deal with the principles which should govern the sponging operations, as these are practically independent of the details of the method used.

In the first place, the water used should be measured, and the flour weighed. When a doughing machine is employed this is particularly necessary, and is highly advisable even when the sponges are set by hand. The blended flour may be weighed off, as mixed, into the right quantities for each batch. In the case of the water, not only must it be measured, but also its temperature is a matter of vital importance. In determining temperature, the first consideration is that which is required for the set sponge. A number of bakers work both their sponges and doughs at too high a temperature; a golden rule is to work at as low a temperature as possible provided it does not actually starve the fermentation. The best temperature for working sponges is somewhat between 75° and 80° F.; while in the hottest summer months a temperature even below this may be adopted. In the next place, the temperature of the flour should be ascertained, then that required for the sponging water may be determined on the principles laid down in paragraph 37. When large quantities of a ferment are used it may be necessary to provide for it in arranging the temperature: the method of so doing is fully described in paragraph 35. These points being decided, there remains for consideration whether or not any salt is to be added to the sponge. As a rule, a small quantity is so added, its object being to prevent sourness by restraining the action of acid ferments. It at the same time slows down the speed of the ordinary alcoholic fermentation. The sponge having been set, is placed in a situation where it will keep fairly warm, and particularly where it will not be subject to chill from draughts. On the other hand, the place must not be warm enough to unduly raise the temperature of the sponge, as this naturally rises during the fermentation. Much will depend, in this respect, on the season of the year; the baker will be guided by his judgment on this point. It need only be mentioned that successful sponging is the keystone of the arch of the bridge over which the baker must travel in order to attain the object of a loaf fulfilling all conditions of excellence.

During the time the sponge is working, alcoholic fermentation proceeds at the expense of the natural sugars of the flour. The gluten is also being softened, and the soluble albuminoids acquire that special activity before described. With hard, sound flours it is doubtful, however, whether, under ordinary circumstances, there is any sensible amount of conversion of the starch of the flour into gum and sugar.

(For detailed information of this point consult the paragraph of *Chemistry of Wheat, Flour and Bread*, by the author.) The fermentation proceeds vigorously until all or most of the sugar is exhausted, and then almost stops. If the sponge be still allowed to lie, a slow fretting fermentation proceeds. This is most likely the result of fermentation of sugar slowly produced by the diastasis of the starch. If the sponge be allowed to attain this stage, there is imminent danger of its producing sour bread. It has already been mentioned that acid fermentation proceeds with more readiness in a very dilute solution of sugar. It would seem that while the yeast is the more vigorous plant, and can thrive and work at lower temperatures then can the acid ferments, yet it requires its food-stuff, sugar, to be in greater abundance. Further experiments show that vigorous yeast growth in itself is antagonistic to acid fermentation. Toward the end of the working of a sponge the yeast must be comparatively inactive, because of the action of saccharine matter. This removes a check on acid fermentation, and also on the growth and development of acid ferments. Further, the temperature of a sponge naturally rises during the time it lies, and as overworked sponges are frequently a result of too high a temperature, there is thus another check to acid fermentation removed. The student should gather from this the reasons why overworking the sponge, or working it at too high a temperature, is so injurious. It is customary to take compressed yeast sponges comparatively early, that is, before the whole of the sugar is exhausted : brewers' yeast sponges can, with safety, be allowed to remain longer, the bitter principle present prevents the development of acid fermentation.

One of the most useful guides to the baker in determining when his sponges are ready is their appearance. As fermentation proceeds the gas inflates the sponge and raises it to near the top of the trough. Ultimately, the distended gluten can no longer bear the strain, and bursts; the gas escapes with a sighing sound, and the sponge "drops." It gradually rises again with further production of gas, and may again drop. This rising and falling is not altogether governed by the degree of ripening or maturity of the sponge : the actual shape of the trough must affect it. Thus, a sponge will drop sooner in a relatively large-surfaced shallow trough than in a deep and narrow one, because in the latter the sides of the trough itself help to retain the gas. Still, there is sufficient connection between this rising and falling and the maturity of the sponge to make it a most valuable guide. A frequent rule is to take the sponge with compressed yeast on its first turn, that is, when it commences to drop. Others will allow it to drop fully, or take it on the second rise. With brewers' yeast the sponge is allowed to remain longer, say, until the top of the second rise, or even after the second drop. The variations in the time of taking the sponge may, very possibly, be caused by actual differences in proportions of troughs, slackness at which sponges are made, and so on. If the conditions are such that the gas tends to escape from the sponge more rapidly, it may very naturally follow that the same stage of maturity is represented by a greater dropping of the sponge.

In consequence of this reliance on the drop of the sponge, bakers are very careful not to shake a trough containing one, especially during its latter stages, as such shaking causes the sponge to drop prematurely. In fact, most bakers hold the opinion that a shaken sponge never works well after. It is difficult to see how the mere shape can effect the fermentation. It is most probable that these shaken sponges work faultily because, having dropped, they are liable to be taken before ready.

When sponges are taken before they are thoroughly ripe or matured, the bread is small, and frequently foxy in the crust. With a sponge that has worked too long the loaf tastes yeast-bitten, and is exceedingly likely to turn sour. The reason for this has already been explained. The rapidity with which a sponge works is affected by three causes: 1st, the quantity of yeast used; 2nd, the temperature; and 3rd, the kind of flour. If it be necessary to accelerate the speed at which it works, this is usually best done by increasing the quantity of yeast, unless the baker is working at such a low temperature as actually to tend to render the yeast inactive. But usually slow sponges are best remedied by setting them earlier. Little yeast, low temperature, and plenty of time generally give the most successful results. Comparatively soft flours work much more rapidly than hard, and, consequently, with these the sponge is ready sooner. It should then be set later. A slack sponge also works more rapidly than a tight one.

96. Doughing.—The sponge being ready, the next step is to make the dough. Here, again, the water should be measured and the flour weighed if the most regular and economic results are desired. When working by hand, the trained baker is able to judge very closely by the feel of his dough whether or not it is of the requisite stiffness ; but it is different with a machine. The blades of a doughing machine revolve much the same whether the dough is too slack or too stiff ; therefore, here especially, it is necessary to weigh the doughing flour. The temperature at which the doughing water is taken will depend somewhat on the length of time before which the dough is required. Frequently two doughs are made in immediate succession, one of which will be wanted on the moulding table, say, half an hour before the other. The latter is set at a rather lower temperature.

In making the dough, the sponge is frequently first broken down with the water, the salt is added, and then the flour worked in. The same course of proceeding is often adopted when a machine is used. There are some types of machine which do not lend themselves readily to breaking down a sponge, owing to their having been so designed as to be free from any cutting or tearing action. These have the compensating merit that the sponge, extra water, and flour, may be added altogether in the machine, and then thoroughly mixed and kneaded, without any necessity whatever for first breaing down the sponge.

The quantity of salt used in bread-making varies considerably, from about 3 lbs. in some districts to about 7 lbs. in others. The taste of the locality will, to a certain extent govern the quantity. Salt somewhat retards fermentation, and in particular acts as a preventive of sourness. In the case of very weak flours, salt exerts a binding effect, and so is frequently used in greater quantity with flours deficient in strength.

The operation of doughing will have deprived the sponge of much of its gas ; but with the addition of new flour fermentation once more sets in with vigour, especially as soft flours containing sugar in comparative abundance are used at this stage. Before long the gas will cause the dough to expand to twice or more its original size : at this stage many bakers "cut back" or "knock down" the dough. The cutting back generally consists of cutting off convenient-sized pieces of dough and rekneading them, folding them during that operation over and over. The whole mass is thus treated. One object of this treatment is to give the bread somewhat of a fibrous texture. In the knocking down, the gas is simply forced out of the dough by pushing it forcibly down in the trough. Why should the dough be thus knocked down; why not at once as soon as it is sufficiently lightened get it into the oven? The answer is an interesting one; bakers will say, if baked too soon the bread is cold and raw in flavour, by which it will be harsh, and possess other undesirable properties. These are the results of the bakers' own experience. Now let us see what are the reasons which underlie this. Fermentation has two distinct objects, one of which is to aerate the bread by the production of gas within it. The second is to permit certain changes to proceed in the glutinous constituents of the flour. These gradually get softened and changed into peptone, which, as has been explained, is an intermediate step toward digestion. The result of allowing this change to proceed sufficiently far is that the albuminoids are far more digestible, and are also more pleasant to the palate. Frequently the production of gas by fermentation is sufficiently advanced before the changing of the albuminoids has progressed as far as desirable, hence the gas is forced out, and more allowed to form. In this matter much will depend on the hardness of the doughing flour; when very soft, but little waiting is necessary. The next question is the consideration of when the doughs are ready. They should, in the first place, be full of life; the dough should, in texture, be fine, silky, and elastic; but at the same time not too tough in its resistance to being torn. If the sponge is taken too soon the bread is liable to bake foxy owing to its still containing saccharine matter in large quantity. Also, the bread will be small; this is due partly to being insufficiently charged with gas, and partly to the albuminoids not being sufficiently softened. The loaves are, in fact, "gluten bound." On the other hand, if the doughs are allowed to remain too long, the bread may be large, but is liable to become runny through the gluten being too soft to hold the loaf up. In appearance the bread will be white, and the crust pale. To the taste the bread will be flavourless, or else may be even sour ; while on keeping, sourness is liable to develop to a serious extent. On being cut the loaf crumbles, and can only with difficulty be made to yield good slices of bread and butter.

97. Scaling, Moulding, and Proving.—These operations are principally mechanical in their character, and will require simply passing reference here. In moulding, the object is not merely to produce a round lump of dough, but, further, to give it a different texture, which shows distinctly when the baked loaf is cut. Bakers usually mould or hand up bread twice, once immediately after scaling, and then again just before the bread goes into the oven. During the interval the loaves are placed in drawers or covered boxes to "prove," that is, to again get somewhat filled out by the production of gas. After the second moulding the bread again requires more or less proof before going into the oven. The amount of proof here permitted must, of necessity, somewhat depend on the character of the flour ; where highly sound and elastic they will improve by standing some time, but when a high proportion of soft flours is employed the loaves show symptoms of running, and will bear comparatively little proof.

98. Baking.—The loaf being placed in the oven, we have next to consider those changes which are due to the action of the high temperature. First of all, with the rise of temperature the yeast is stimulated to increased energy, and more gas is produced within the loaf. This, however, is but a temporary action, for before long the temperature rises sufficiently to entirely arrest fermentation. During the same time, the gases produced are being expanded by the action of heat, and as the interior of the loaf approaches the baking temperature, steam is produced. As a result of these combined actions the loaf increases very considerably in size within the oven. The temperature within the loaf kills the yeast plant before baking is completed, so that it is impossible, in properly-baked bread, for it to set up alcoholic fermentation. The starch of the flour is swollen and gelatinised by the heat ; the active albuminoids present more or less attack this gelatinised starch, converting it into dextrin and maltose. They in their turn shortly, however, are coagulated, and so lose all power of acting on starch, either within the loaf or subsequently when the bread is eaten. As the interior of the loaf is even, after baking, abundantly charged with water, it is impossible for its temperature at any time to rise above that of the boiling point. The exterior of the loaf is subjected to more intense heat, and is changed considerably in character, forming the crust. The crust tastes decidedly sweet, owing to the change under the influence of heat, of its starch more or less into maltose and dextrin. The action of the heat further changes a portion of these bodies into caramel, and so gives the crust its yellowish brown hue. Bread loses considerably in weight by evaporation while in the oven; as a consequence of this, 4 lbs. 6 ozs. of dough are usually taken in order to produce a 4 lb. or "quartern" crusty loaf.

99. Cooling and Storage of Bread.—On being removed from the oven, bread should be permitted to cool in an abundance of fresh air. The loaves should be so stacked as to permit of free ventilation between them, and the bread should not be packed until cold and firm.

100. Souring of Bread.—This is, unfortunately, one of the great evils with which the baker has to contend. Some of the causes have already, in passing, been pointed out; with advantage these may again be recapitulated. There is first of all the use of impure, unhealthy, and weak yeast. The presence in this of disease germs, and the opportunities they have of actively developing in the absence of energetic action of the yeast, has been commented on. The remedy in this case is evidently the selection of a better yeast.

But there are times when one quality of bread may be perfectly sweet, while another, whose only difference is in the flour used, is too often sour. In this case it is evidently the yeast which is not at fault, but the flour. Sourness is often caused by the use of unsound or very low-grade flours. It often happens that with these the effort is made to use as much water as with flours of a stronger nature; in consequence, the doughs are made slacker and ferment more rapidly. Part of the cause of sourness in this case is that the albuminoids get broken down to a very large extent, and also some of the starch is changed into dextrin. The resultant mass is peculiarly adapted to acid fermentation, and so a sour loaf is the result.

So far, we have been dealing with a danger of sourness arising from faults in the materials used. Let us now glance at dangers inherent to the actual working operations. First of all, there is want of cleanliness in the tubs, troughs, and other utensils. It has been already insisted that tubs should be scalded out with either hot water or steam. All troughs and penboards must every day be thoroughly scraped out *especially in the corners*, so that not a vestige of old dough can remain in them. In case any sour bread is obtained, and as a precaution in summer time against its recurrence, the troughs may be cleaned in the following manner: On a Saturday, as soon as the troughs are out of use, let each be washed with hot water; then take some solution of bisulphite of lime (or sulphurous acid, which answers the same purpose), and sponge the troughs out with this; let some of the solution run down each of the corners and round all the joints, as these are especially the places where disease ferments may be. Then cover the troughs in with the lids and let them stand till the evening. They must then be uncovered, and by the Sunday they should be quite dry and free from the smell of sulphur dioxide.

One of the most common working causes of sour bread is the adoption of too high a temperature; this in itself favours acid fermentation. It also so frequently leads to over-fermentation that this second precursor of sourness follows in its train. The obvious moral, as before insisted on: if sponges or doughs are not ready when required, set them earlier; or, if this is impracticable, let more yeast be used.

But there is little doubt that over-fermentation is one of the most frequent causes of sourness. The weather becomes unexpectedly much warmer; a moderately cold forenoon is followed by a more than usually warm afternoon; or, after an ordinary afternoon, the evening has the sultriness of an approaching thunderstorm. As a consequence of the rise in temperature, the fermentation is hastened, and sponges are ready some time before the workmen come in to take them. Here we have a cause of sourness almost beyond the control of the baker. But there are other similar causes, which too often are the result of direct carelessness on the part of the workman; in order to hurry things up, and so get to the end of the morning's work, sponges and doughs are set too hot, and so overwork themselves before they are wanted. All this can be remedied by reasonable care and patience.

Insufficient baking is also an additional spur to sourness in bread; the dough not being thoroughly cooked or "soaked" in the centre remains in just that state which most lends itself to sourness. One curious point in connection with this is that sourness develops itself *after* the loaf is baked. A loaf may be perfectly sweet both to the smell and taste when it leaves the oven, and even when cool, and yet may become sour in the course of a few hours. Further, this tendency to sourness is a result of what has occurred to the bread before baking. Thus bread from overworked sponges is frequently sweet immediately after cooling and becomes sour afterwards. This fact, that the causes of sourness precede baking and the effects follow that operation, points to baking not being a process which entirely destroys the cause. That cause, it will be remembered, is the presence of acid ferments. We are therefore led to the conclusion that these survive the heat of the oven, and produce acid fermentation after the bread has become cool.

The conditions to which bread is subject while cooling also affect its sweetness. If cooled in fresh air the bread may remain sweet, while if cooled in a damp and confined space, sourness is a frequent result.

101. Scotch Modes of Bread-making.—These differ considerably in details from those employed in England, but the principles are much the same throughout. Potato ferments are not commonly used in Scotland; where flour barm is employed, that constitutes in itself the ferment. In what are called half sponges, one-half the total liquor is used in the sponge; while in the quarter sponges, one-quarter of the total liquor is so used. The sponges are usually made with all spring American or hard Russian flour, and are allowed to stand from twelve to fourteen hours. The doughs altogether stand about one and a half hours, and are cut down and turned once during that time. About an hour to one and a quarter hours are allowed for scaling, moulding, and proving. Scotch bread is largely made in a close-packed form, and has a very characteristic appearance. The loaves are high, and the joints between each are distinguished by a remarkably fine silky texture or "pile." The result of the very long fermentation and the use of flour barms, containing a considerable quantity of lactic ferments, is that the bread itself has always a slightly acid flavour. This is not accidental, but intentional.

102. Whole-Meal Bread.—Some people like bread which has been made not from white flour, but from meal, containing in addition the bran and germ of the wheat. Whole-meals are at the outset liable to the very grave objection that they rapidly heat and become musty. This is an action largely due to the presence of the germ. The actual structure and object of this part of the grain has been already explained. In composition the germ is largely composed of soluble albuminoids, and, hence, in its natural state, although very nutritious, is objectionable in both flour and dough, as it acts on the starch of the flour. Whole-meal, therefore, requires to be used in a fairly fresh condition. During the ordinary processes of bread-making, the cerealin which is thus introduced by both germ and bran causes very serious action on the starch of the flour. It is because of this that there is such a tendency on the part of whole-meal bread to become sodden as the result of the great softening of the albuminoids and also the conversion of starch into dextrin. This soddenness leads to the bread being baked unusually long in order to "soak" it as thoroughly as possible. Owing to its very unstable nature whole-meal should be fermented at as low a temperature as possible, and for a short time; vigorous fermentation must be ensured by the employment of plenty of yeast.

An interesting variety of brown bread is that made from germ which had its diastasic power destroyed by the action of slightly superheated steam. This germ is then mixed in with fine white flour. The resultant mixture is far more nutritious than whole-meal, and has not the same tendencies to become sour or sodden during fermentation.

103. Aeration of Bread by Acid and Soda.—To a certain extent acid and soda are used in bread-making as a substitute for yeast. All bakers are familiar with the use of these substances to lighten scones and other small goods, as well as cakes. The action is a simple one, and is represented in the following equation:

$$\underset{\text{Tatarric Acid.}}{H_2C_4H_4O_6} + \underset{\text{Sodium Bicarbonate Soda)}}{2NaHCO_3} \underset{\text{Sodium Tartrate.}}{Na2C_4 = H_4O_6} + \underset{\text{Water.}}{2H_2O} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

The displaceable hydrogen of the acid is replaced by the sodium of the carbonate forming tartrate of sodium, and carbon dioxide gas is set at liberty. This gives the requisite sponginess to the loaf.

At times cream of tartar is used instead of the acid. This body is tartaric acid, in which one-half of the displaceable hydrogen has been replaced by potassium. When used the following is the chemical change which occure:

$$\underset{\text{Cream of Tartar.}}{KHC_4H_4O_6} + \underset{\text{Sodium Bicarbonate.}}{NaHCO_3} = \underset{\text{Potassium Sodium Tartrate.}}{KNaC_4H_4O_6} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon Dixoide.}}{CO_2}.$$

The action is in this case slower, owing to the comparative insolubility of the cream of tartar.

104. Aerated Bread.—This bread is also raised by the action of an acid and carbonate in each other; but with this great difference, that the chemical action is produced in a separate vessel, and the gas then mechanically forced into the dough. In this way much cheaper substances may be employed for the production of the gas, as the residual products are simply thrown aside. The substances most generally employed are limestone (calcium carbonate) and sulphuric acid.

$$\underset{\text{Sulphuric Acid.}}{H_2SO_4} + \underset{\text{Calcium Carbonate.}}{CaCO_3} = \underset{\text{Calcium Sulphate.}}{CaSO_4} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

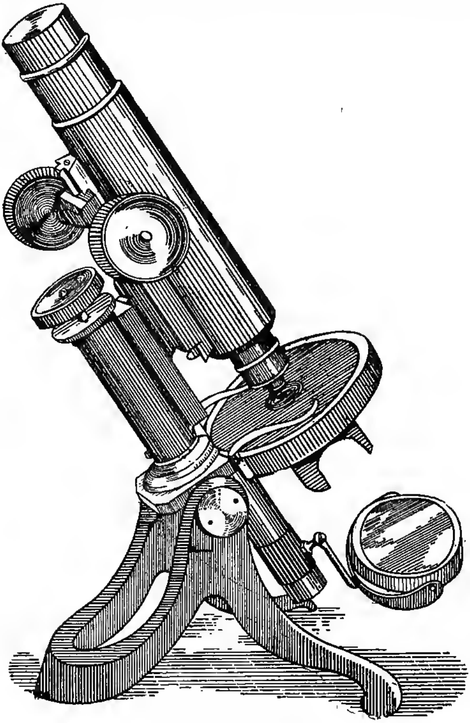
The evolved gas is dissolved in water by being forced into it by pumping machinery. The carbon dioxide solution is then used for making the dough, which operation is performed in stong globular receivers. On opening a valve at the bottom of the receiver the dough rushes out, and with the liberation of pressure the carbon dioxide escapes from its solution, and so aerates the dough.

CHAPTER VI.

YEAST AND FLOUR TESTING.

105. Use of Microscope.—This instrument is of great value in the examination of both yeasts and flours; reference has frequently been made to it incidentally in former chapters. It is almost impossible within the scope of this work to give any extended directions for its use ; still, the following few hints may be of service to those who cannot readily obtain information elsewhere. They will best be supplemented by a study of the author's larger work, *Chemistry of Wheat, Flour, and Bread,* which deals exhaustively with all the practical details of both yeast and flour testing, and to which this little book is written as an introduction.

The illustration given in Figure 14 is of very useful and ordinary type of microscope for general purposes. The instrument consists, first of all, of a stand, which serves the



FIP. 14.—COMPCUND MICROSCOPE

purpose of holding the lenses necessary, and also the object to be examined. A compound microscope consists of two sets of lenses ; one of these sets is called an objective or object glass, and is screwed into the lower end of the main brass tube of the instrument. At the upper end the upper series is placed, and is called the eye-piece or ocular. The eye-piece slides in and out of the top of the tube. In order to obtain different degrees of magnification, the objectives are made of different degrees of power. The more powerful they are the nearer they have to be brought to the object in order to see it distinctly. They are commonly known and spoken of by the distance they have to be away from the object. For a baker, very useful objectives are those known as an "inch," and also the "eighth." When the funds are sufficient, a "twelfth water immersion" is also a very useful objective The two former can be obtained first, and the latter at any subsequent time if wished. The eye-pieces also vary in power ; what is known as a "B" eye-piece is suitable for most ordinary work. These, then, are the first things necessary in conjunction with the microscope stand. There are also certain other minor accessories necessary. Among these are, say, a couple of dozen glass slides, some thin glass covers about ¾-in. round or square, a piece of glass rod, one end rounded and the other drawn out to a point, and a small piece of glass tubing. All these can be obtained from the instrument maker.

Next, as to the use of the instrument, the actual mounting of specimens of starch, &c., on the slide, and placing the cover over them, has been already described. When about to look through the microscope, first level the tube until at a convenient angle for the eye, and screw into its place the objective it is wished to use. A good source of light is necessary. This may be obtained from a window, or the light of a small paraffin-lamp. Underneath the stage of the microscope will be found a moveable mirror. Twist this until it reflects a ray of light falling on it directly up through the microscope. This is readily observed by looking down through the instrument, for as soon as the light is turned on the field of vision is perfectly bright. Next put the slide, holding the preparation to be examined, on the microscope stage. Slowly and carefully lower the tube by means of the screws at each side, looking all the time through the eye-piece, until the object is in focus; that is, appears clear and distinct, and not blurred.

With the higher powers the final adjustment is best made by means of the "fine adjustment," governed by a single screw usually at the back of the instrument. Any object seen through the microscope is inverted; that is, the top is seen at the bottom, and the left side at the right.

106. Yeast-Testing.—The principal tests on yeast are those for freedom from foreign organisms and the healthy character or otherwise of the yeast cells themselves. This is a microscopic test, and has already been explained in the chapter on fermentation. It should be remembered that healthy yeast cells are firm, and the interior contents granular in appearance. Unhealthy cells are frequently watery and flaccid; while under a very high power a distinct movement can be observed in the fluid in the interior. In examining samples of yeast, first note the presence or absence of starch. Next look for foreign ferments; these should be absent, or at least present in but small quantity. In brewers' and compressed yeasts they should be absent. Among the foreign ferments, lactic organisms are the least objectionable; in fact, as has been stated, their presence in small quantity is considered an advantage in Scotch flour barms. The presence of the ferments of putrefaction in any but the merest traces is strongly condemnatory of the yeast. Attention should next be turned to the condition of the yeast cells themselves, and an opinion thus formed as to their healthiness or otherwise.

As an exercise in the microscopic examination of yeast, the student should take as many samples as possible of fresh brewers' and compressed yeasts, and then examine them day by day until they get perfectly stale. Practice of this kind will educate the eye in a manner nothing else is capable of doing.

The presence of starch is revealed both by the iodine test and by the microscope.

The "strength" or gas-evolving power of yeast may be determined by careful tests made by fermenting with small quantities of yeast. It is essential that the temperature be under thorough control, and also substance used for fermentation must be the same in amount and uniform in composition. Either flour or sugar may be used for the purpose according to what kind of information about the yeast is desired. The yeast, flour, or sugar, as the case may be, and the water are weighed at the desired temperature, then mixed with all necessary precautions and placed in a suitable vessel. This vessel is arranged so that its temperature shall remain constant throughout the whole test. As fermentation proceeds, the evolved gas is conducted into a graduated tube and its volume there read off. The stronger the yeast the more rapidly it causes the evolution of gas.

107. Flour-Testing.—For ordinary commercial purposes it is customary to make the following tests on flours: examination of colour, determination of gluten, and water-absorbing power. In addition, the flavour is a most important characteristic of flours. It is at times advisable to test flours for impurities and adulteration. Among these have been found earthy matters, flour or starch from other varieties of grain, and alum.

108. Colour.—To estimate the colour of a sample of flour, proceed in the following manner: With a spatula or clean knife take a small quantity of the flour and smooth it out on a piece of board, or little sheet of zinc plate. If two samples are to be compared, treat them in this way side by side. Note the relative whiteness and bloom of the two flours. When more than one flour is thus being treated it is a good plan to arrange the samples side by side, and then press them as flat as possible by means of a piece of plate glass, the front of which has wrapped round it a piece of highly-glazed writing paper. The flour is thus compressed into a more coherent cake or slab. Having examined the flours in a dry state, next steadily dip a sheet of zinc with the flours obliquely into a vessel of clean water. Allow it to remain for half a minute and then steadily withdraw. Again examine; the colour will represent that assumed by each flour in the dough. Note the comparative freedom or otherwise of the flour from bran; as when wet this is seen with great distinctness. Set the flours where they will be free from dust, and let them gently dry; examine again at the end of twenty-four hours. An ingenious instrument, termed the tintometer, has been invented by Lovibond, by which the tint of each flour may be measured and permanently registered for the purposes of comparison.

109. Gluten.—The method of separating gluten has been already described. When it is wished to know the exact percentage, the following method may be adopted:

In the first place, ordinary ounce measures are not well adapted for this work. The best plan is to procure a set of metric weights, which can now be very cheaply obtained. The unit weight is called the gram, and weighs 15.432 grains; or 28.35 grams weigh 1 oz. Then as multiples and subdivisions, we have 10, 100 and 1,000 grams, and .1, .01, and .001 parts of a gram.

Weigh out, on a delicate balance, 10 grams of flour; to this add about 6 grams of water. The quantity will depend on whether or not the flour has a high water-absorbing power. With one of the flour-testing burettes, to be subsequently described, 14 to 15 quarts on the burette is a convenient quantity of water to take. In a small bowl mix these thoroughly together into a smooth and even dough. Place this dough in a small cup, and cover it with water. At the end of an hour remove it, and wash either naked in the palm of the hand or enclosed in a small square of fine bolting silk. The latter is the easier, but the former is the quicker mode of working. If the silk is used, first wet it, then place the dough in the middle; fold up the corners so that no gluten can escape, and commence to wash it gently under a small stream of water from a tap. The running water is rendered milky by the escaping starch. As soon as it is quite clear, open the silk and remove the gluten, which will be found as a ball in the centre. Give this a little more washing without the silk. If no silk at all is used, the naked dough is washed in the same manner; great care must be taken to avoid the loss of any particles of gluten. Shortly, sufficient skill is attained to ensure gluten being thus washed without any loss. Having obtained the gluten free from starch, squeeze all superfluous water out of it, wipe the outside dry, and weigh. Suppose the weight is 4.16 grams, then the percentage of wet gluten must be 41.6, because 10 grams were taken for the test. Note the colour of the gluten, also whether tenacious and elastic, or short and ragged. To do this, pull it about and mould between the fingers. Lastly, mould the little lump of gluten into as round a ball as possible, and set it aside on a glass plate in a dry and moderately warm place. After twelve hours have a look at it, and notice whether it has run much. If the flour is hard and sound it will have flattened very little; while with very soft flours, especially if from unmixed wheats, the gluten will have become semi-liquid. Note: if it is wished to observe the colour of the gluten, the hands must be scrupulously clean, and be thoroughly washed immediately before the test is made.

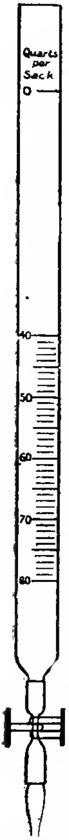


Fig. 15. Flour-testing Burette.

It is advisable also to determine the weight of the gluten when dry. This is best done by first drying the gluten in a hot-water oven. This is an apparatus heated by boiling water, which prevents the temperature from rising above 212° F. In the absence of this, some place may be found, either over the ovens or in a prover, in which the temperature does not rise over the boiling point. The gluten may be allowed to remain there until it no longer loses in weight. Approximately, dry gluten weighs about one-third of the weight when in the wet state. It may perhaps be as well to point out the best way of handling gluten in order to dry it. The ball of gluten may be placed, together with the glass plate on which it stands, in the oven. After a little time, when a crust has formed on the top, loosen it from the plate by means of a sharp knife, and turn it over, and again replace in the oven. The dry piece may then be placed from time to time on the balance pan, and weighed in the usual manner.

In a letter to which reference has previously been made, Mr. Thoms suggests the advisability of indicating the importance of weighing the gluten dry; this the author had already done, but thinks Mr. Thoms' remarks on the subject show so clearly the differences between wet and dry gluten, that in a condensed form, they are here inserted: "The weight of hand-dried or pressed gluten after washing, is not alone a proof of either quantity or quality. On the contrary, Nos. 2 and 3 spring-wheat flours will give a higher weight of wet gluten than spring No. 1 hard, because it is weaker, less mature, hydrates or takes up water faster, and holds it more tenaciously against mere mechanical pressure than the higher quality in No. 1. In washing, the frothing has to be noted; the gluten, as gluten, is inferior in proportion to the amount of frothing. Flour is not of value for bread-making in proportion to the quantity of gluten in it. The percentages (dry) will be found to range between 9 and 18 in spring flours, but the sample containing 12 per cent. will be found the best in bloom and bread-yield. Over this percentage it becomes darker and coarser; under, there is a tendency to weakness. As to the gluten of winter-wheat flour for *bread*, so long as it is sound the highest percentages are best, but for *biscuits* the lowest are best; that is, the lower percentages found in white winter-wheat flour are preferable to the higher precentages in red winter.''

110. Water-Absorbing Power.—This is largely dependent on the dryness of the flour, and is determined on the principle of ascertaining what quantity of water the flour will take in order to make a dough of standard stiffness or consistency. A piece of apparatus devised by the author for this purpose is shown in figure 15.

This is a glass measuring vessel such as is commonly employed by chemists, and is termed a burette. As will be seen on inspection of the figure, it consists of a long glass tube, which in this case is graduated on its lower half. These graduations are of such a value that when 1½ oz. of flour are taken, each graduation is exactly equivalent to a quart of water to the sack (280 lbs.) of flour. At the lower end of the tube a glass jet is attached by means of indiarabber tubing. A spring clip pinches this tube tight.

To make a test, weigh out exactly 1½ oz. of the flour and place it in a small bowl or cup; next fill the burette with water. Press the buttons on the spring clip, and allow the water to run away until its level exactly coincides with the 0 or zero mark near the top of the burette. Water in a small tube like this has a hollow concave surface. In using a burette one always reads from the lowest part of this curved surface (''bottom of the meniscus,'' as it is termed). Next hold the burette over the bowl with the flour, again press the clip, and let the water run out until fifty-five or sixty, or whatever other number of quarts has been added that is thought desirable. Remove the pressure and the water ceases to run.

For a number of samples of flour—in fact, whenever the instrument is in systematic use—it should be fitted with reservoir, as shown in Figure 16.

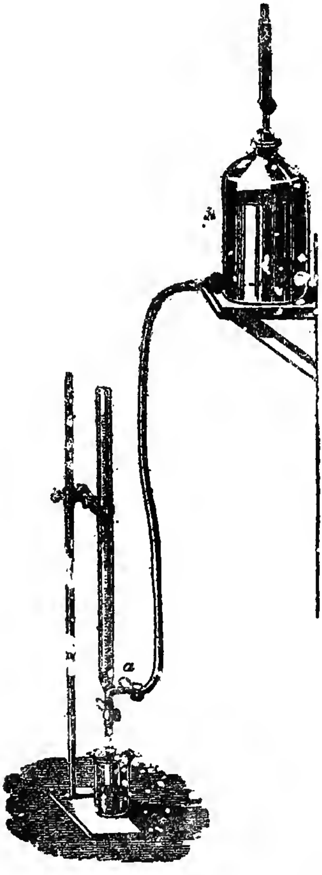


Fig. 16.—Flour-Testing Burette with Stand and Reservoir

In this figure the burette is shown fixed in a stand, which to start with is a matter of great convenience. On examination it will be seen that at *a* a second tube opens into the bruette above the spring clip, by which the water is let out into the flour. This second tube connects the burette with the reservoir A, which is placed on a shelf above the level of the burette. At *a* is a second clip, by which the reservoir is shut off from the burette. To use this arrangement, the burette being empty, press the clip *a*, water from the reservoir rushes in and fills the burette to the graduation mark. Then release the clip, and open the bottom clip to let out the desired measured quantity of water as before.

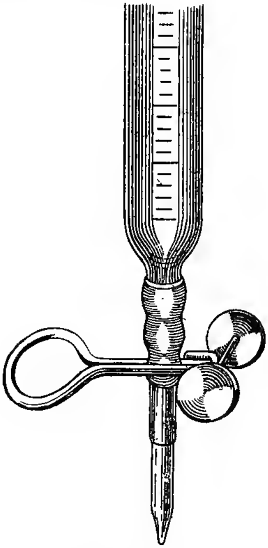


Fig. 17.—Lower End of Burette and Spring C

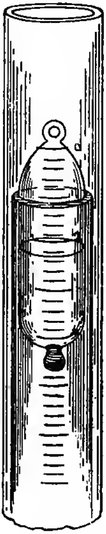


Fig. 18.—Erdmann's Float.

In figure 17 the lower end of the burette is drawn together with the clip, thus showing more clearly the nature of the clip arrangement. Reference has already been made to the curvature of the surface of the water in the burette. This is a source of difficulty in reading with many. This difficulty may, however, be altogether got over by the use of what is called "Erdmann's Float." This little piece of apparatus which is shown in Figure 18, consists of a piece of glass tubing of such a size as to readily slide up and down within the burette. This tube is closed at both ends so as to form a long glass bulb, which is weighted with a small quantity of mercury. Around the float a small single line ***a*** is cut with a diamond. In using the float, it is dropped into the burette, and this line is brought to agree with the zero at starting, and afterwards at the graduation to which it is desired to run out the water. These little additions add wonderfully to the rapidity, ease, and accuracy with which the instrument can be used.

Having measured in with the flour the desired quantity of water, proceed either with a glass rod or bone spatula to work the water and flour up into a dough. If before quite mixed the dough is found to be too tight, a little more water may still be added from the burette. If too slack throw away the dough and make a fresh start with less water. In this way proceed to obtain a dough of what is considered a proper consistency for the bread you wish to make. The number of quarts of water used according to the burette is the quantity which may be added to the sack of flour. In comparing a number of flours, every quart of water difference may be taken as representing roughly a difference in the yield of a half-quartern loaf. (The quart of water weighs 2½ lbs.)

A word of caution may be inserted here as to the valuation of flours in so far as their water absorbing capacity is concerned. Suppose of two flours, alike in every other respect, that No. 1 absorbs sufficient water to yield 94 quartern loaves, while the second yields 96 such loaves. The bread sells at 6d. per quartern. A very prevalent error is to assume that the second of these two flours is worth a shilling a sack more than the first. This arises from taking the extra yield at its selling value as a finished product. Really its extra value is simply the cost of flour as the raw material in these two extra loaves. Let us suppose that the first of these two flours is worth 30s. a sack, and then proceed to ascertain the value of the second. We simply have the proportion. As the yields of the two flours are to each other, so are their respective values :

	Quarterns.		Quarterns.		s.	d.		s.	d.	
As	94	:	96	: :	30	0	:	30	7½	=value of No. 2 flour

The immense importance of this to the baker needs only to be pointed out to be fully appreciated.

Mr. Thoms, of Alyth, has devised a water-testing apparatus the principle of which is the same. Mr. Thoms, however, has adopted the pipette instead of the burette form, and graduates his instrument into drachms and half drachms of water. He has also published a very useful table, in which the bread-yield for each quantity of water absorbed is given.

For kneading these small test doughs the author employs a very small doughing machine, made specially for him, with revolution counter attached. He also uses a special form of apparatus, termed a viscometer, for mechanically measuring the stiffness of the dough. Want of space precludes a description of these instruments in this place.

111. Baking Tests.—In addition to tests, such as those just described, it is well to make baking tests on small quantities of flour. Either 7 or 3 lbs. may be used for this purpose. The former quantity has the advantage, that every ounce of water represents a quart to the sack. In the following table the quantities of water in ounces to 3 lbs. of flour are given, together with their equivalents in quarts to the sack :

50 quarts —	21.4 ounces.	58 quarts —	24.8 ounces.
51 ,,	21.8 ,,	59 ,,	25.3 ,,
52 ,,	22.3 ,,	60 ,,	25.7 ,,
53 ,,	22.7 ,,	61 ,,	26.1 ,,
54 ,,	23.1 ,,	62 ,,	26.6 ,,
55 ,,	23.5 ,,	63 ,,	27.0 ,,
56 ,,	24.0 ,,	64 ,,	27.4 ,,
57 ,,	24.4 ,,	65 ,,	27.8 ,,
66 quarts —	28.3 ounces.	74 quarts —	31.7 ounces.
67 ,,	28.7 ,,	75 ,,	32.1 ,,
68 ,,	29.1 ,,	76 ,,	32.6 ,,
69 ,,	29.6 ,,	77 ,,	33.0 ,,
70 ,,	30.0 ,,	78 ,,	33.4 ,,
71 ,,	30.4 ,,	79 ,,	33.8 ,,
72 ,,	30.8 ,,	80 ,,	34.3 ,,
73 ,,	31.3 ,,	81 ,,	34.7 ,,

The flour must be weighed, and also the requisite quantity of water, salt, and yeast. The whole may then be mixed right away into a dough, or a thin batter sponge may be made in the middle of the flour with the whole of the water. In the latter case the little sponge must, after a time, be worked into the rest of the flour and the dough thus made.

When fermentation has proceeded sufficiently far the dough is moulded into loaves ; note is taken of the elasticity of the dough, and whether it works and handles well. The loaves are then baked, and a judgment is formed on their general appearance, quality and flavour. The loaves may be weighed, and thus an estimate made of the yield of the flour per sack.

112. Presence of Flour from other sources than Wheat.—If rice or maize be mixed with the wheat flour the adulteration is readily detected by means of the microscope, as the characteristic shape of the starches reveals their presence. The same may be said of either potato starch, or pea or bean flour.

113. Alum Tests.—One test that may be occasionally of service to the baker is that for alum, which may here be described. The test may be made in the following manner :

Take a few chips of logwood and place them in a test-tube, pour in sufficient methylated spirit to cover them, and stand the tube in warm water for about five minutes. The heat must not be sufficient to make the spirit boil. Very soon the spirit will be the colour of brown sherry ; at this stage it is ready for use. Prepare also a saturated solution of ammonium carbonate (the "volatile" of the baker). This is done by, say, one third filling a bottle with the substance and then filling with distilled water. Shake the bottle from time to time at intervals during twelve hours. In a clean cup or basin mix together thirty drops each of the logwood tincture and the ammonium carbonate solution, and ½ oz. each of the flour under examination and of water. Stir the whole together thoroughly. With pure flour the mixture is of a light pinkish tint. Alum changes the colour to lavender or full blue. The blue colour should remain on the sample being heated in the hot-water oven for an hour or two.

Bread may be tested for alum in much the same way. Crumble down the suspected sample, and add to it the same mixture of logwood, carbonate, and water as was before employed. Let it stand for five minutes, then drain off the superfluous liquid and slightly wash the bread. Alum gives the bread thus treated a lavender or dark-blue colour, which is intensified on drying. Pure bread has first a light-red tint, which fades off into a buff or light brown. By this test as little as 7 grains of alum to the 4-lb. loaf have been detected. The tincture of logwood must be freshly prepared each time, and the test must be made immediately after mixing the logwood and ammonium carbonate solutions.

114. Conclusion.—The time has now come when this little work must be drawn to a close. The author's endeavour has been to place in as simple a manner as possible the most important principles of bread-making before his readers. To grasp and understand anything worth understanding can only be done by some effort on the part of the reader. It is hoped that by mastering the contents of this elementary work many will be stimulated to study still more deeply, and thus elucidate some of the mysteries which still underlie the ancient and dignified art of BREAD-MAKING.

THE END.

INDEX.

ABSOLUTE Temperature, 38
Acetic Acid Ferment, 76
—Butyric, 75
—Carbonic, Carbon Dioxide, 17
—Hydrochloric, 20
—Lactic, 74
—Phosphoric, 21
—Sulphurous, 112
Acids, Bases, and Salts, 19
Adulteration, 126
Aeration of Bread other than by Yeast, 114
Albumin, 63
Albuminoids, 63
Alcohol, 67
Alcoholic Fermentation, 67
Alkalies, 20
Alum, Tests for, 126
Ammonia, 20
Analyses of Flours, 94
Ascospores, 70
Ash of Wheat and Flour, 51
Atmosphere, 16
Atomic or Combining Weights, 13
—Theory, 10
Atoms and Molecules, 10

BACILLUS *Subtilis*, 75
Bacterium Lactis, 75
—*Termo*, 74
Baking, 110
—Tests, 125
Barm, Scotch Flour, 82
Base, Definition of, 19
Blending of Flour, 100
Boiling Point, Effect of Pressure on, 41
Bran, 51
Bread, Aerated, 114
—Cooling of, 111
—Germ, 114
—Souring of, 111
—Test of Alum in, 126
—Whole Meal, 113
Burette, Strength, 121

CALCULATIONS, 29
Cane Sugar, 62
Carbohydrates, 55
—Transformations of, 59
Carbon, 16
—Dioxide, 17
—Monoxide, 17
Cellulose, 56
Chemical Equations, 12
Chemistry, Definition of, 5
Colour of Flour, 119
Combining or Atomic Weights, 13
Combustion, 18, 36
Compounds, 7
Conduction, 43
Convection, 41
Cooling of Bread, 111

DEXTRIN, 62
Diastase, 64
Disease Ferments, 74
Doughing, 90, 107

ELEMENTS, Definition of, 6
Endosperm, 51
Equations, Chemical, 12
Erdmann's Float, 124
Expansion of Gases, 68

FATTY Matters of Flour, 53
Ferment Potato, 88
Fermentation, 65
—Alcoholic, 67
—Butyric, 75
—Definition of, 66
—Effect of Salt on, 108
—Effect of Temperature on, 73
—Lactic, 74
—Putrefactive, 74
Float of Burette, 124
Flour Analyses, Results of, 94
—Barm Formula, 82
—Blending, 100
—Colour of, 119
—Adulterants of, 126
—Testing, 118
Flours, Classification of, 93
Force, Explanation of, 9
Formulæ, Chemical, 11

GELATINISATION of Starch,
Germ, 49
—Bread, 114
Glucose, 62
Gluten, 64
—Results, 121
—Testing, 119

HEAT, Action of, on Water, 39
—Measurements, 23
—Calculations, 29
—Conduction of, 43
—Convection of, 41
—Effects of, 38
—Quantity of, 28

NORTH, SOUTH, EAST, AND WEST, THEY ALL DECLARE

"GLOBE'S BEST."

The fame of "Globe" Side Flue Ovens rests upon a solid basis of real merit. They are the result of specialism in this one class of work extending over many years, and a very different product from the so-called Side Flue Ovens often seen in the Provinces.

Those who have not used these Ovens can have no idea of their marvellous efficiency. They are quickly, easily, and cheaply fired; a solid heat is retained at the lowest expenditure on record; need no attention over week ends or holidays; heat can be immediately raised or lowered to suit different classes of goods, and they give perfect baking results.

They are built as either Single, Double Deckers, or Side-by-side, and the Ovens can be worked independently. Old Ovens can be remodelled to "Globe" Standard at small cost.

DISTANCE NO OBJECT.

Cost of erection is lower than for other Ovens, yet they cost virtually nothing for repairs and last much longer.

Enquiries solicited.

KENT & Co., "Globe" Oven Works,

1, SOUTH GROVE, LONDON, E.3.

Telephone—East 1546.

Heat, Radiation o 46
—Sources of, 36
—Transmission of, 41
Hydrogen, 14
Hydrolysis, 61

IMPORTANT Temperatures, 28
Insoluble Albuminoid, 64
Iodine, Reaction with Starch, 59

LACTIC Fermentation, 73

MALT, 64
Maltose, 62
Matter, Indestructible, 9
Microscope Description of, 115
Microscopic Character of Starches, 56
Milk Sugar, 62
Mixtures, Definition of, 8
Molecular Weights, 13
Molecules, 10

NITROGEN, 15

OXYGEN, 14
—Influence of, on Yeast, 72

PATENT Yeast, 77
Phosphoric Acid, 21
Phosphorus and Phosphates, 21
Physical Structure of Wheat-Grain, 48
Potato Ferment, 88
Proteids or Albuminoids, 63
Putrefaction, 74

QUANTITY of Heat, 28

RADIATION, 46
Respiration, 19

SACCHARIFICATION, 59
Saccharomyces Cerevisœ, 66
Salt, Definition of, 19
Salt, Common Action of, on Fermentation, 108
Scotch Flour Barm, 82
Soluble Albuminoids, 63
Sour Bread, 111
Specific Heat, 31
— — of Flour, 32
Sponging and Doughing, 92, 104
Starch, 56
—Action of Diastase on, 61
—Gelatinisation of, 58
—Hydrolysis of, 59
Starches, Microscopic Character of, 56
Strength of Yeast, 118
Sugar of Flour, 62
Sugars, 62
Sulphur, 20
—Dioxide, 21
Sulphuretted Hydrogen, 20
Symbols and Formulæ, 11

TEMPERATURE, 23
—Absolute, 38
Thermometer, 24
Thermometic Scales, 25

VIRGIN Barm, 82

WATER, 15
—Absorbing Power of Flour, 121
Wheat-Grain, Construction of, 48
Whole-Meal Bread, 113

YEAST, 68
—Action of Free Oxygen on, 72
—as an Organism, 65
—Bakers' Home-made or Patent, 77
—Brewers', 85
—Budding of, 68
—Chemical Composition of, 70
—Microscopic Study of, 68
—Mineral Matters Necessary for Growth of, 71
—Necessity of Saccharine Matter, 71
—Substances Requisite for Nutriment, 71
—Testing, 117
—Virgin, 82

"VERCOSAL"

The New Patent Baking Salt.

This Special Salt, made from Natural Cheshire Brine, is proving a valuable discovery for Bakers.

ITS ADVANTAGES, *amongst others, are—*

IT keeps the Bread moist and fresh for a longer period.
IT produces more Loaves per sack of flour.
IT makes a Whiter Bread.
IT improves the texture and flavour.
IT gives a better bloom to the loaf.
IT does away with all need for Bread improvers.

THE ONLY DIRECTIONS.

Use "VERCOSAL" just like ordinary Salt, **but in place of ordinary Salt,** add half a gallon of water more per sack of flour—it is an excellent magnet for water, which is retained in the bread.

We guarantee "VERCOSAL" to conform with the requirements of the Food and Drugs' Acts.

Price **21/-** per cwt. nett, Carriage Paid, or 6-lb. Sample Bags **2/-** each.

VERDIN COOKE & Co., Ltd.,

Manufacturers of all kinds of Salt,

LIVERPOOL.

THE

Burton Malting Co.'s

BURTON-ON-TRENT,

MALT

FLOUR

Has a reputation for

STANDARD STRENGTH & PURITY

and this High Standard is guaranteed all the year round.

Telegrams—"Tod," Leith. Telephone—Nos. 1011 and 1012.

Our Motto: "Best Value and a Uniform Quality."

A. & R. TOD Ltd.,

LEITH FLOUR MILLS, LEITH.

MANUFACTURERS OF

STRONG FLOUR

FOR LOAF BREAD BAKING

AND

WINTER WHEAT FLOUR

For Biscuit Manufacture, Scones, & Household Baking.

FLODOMETER

25/-

Standardises the stiffness of dough.

45/-

CLOCK

DOUGHMETER

The Carpenter has his Square, the Sailor his Compass, the Sugar Boiler his Thermometer, the Mason his Plumb Line, but the Dough Maker no Gauge to Check his work. Now comes the **DOUGHMETER**, simple and cheap, and 42 Bakers write glowing testimony to its aid in their troubles.

DO YOU DESERVE HELP

if you pass this by? Drop a post card to-night.

WATKINS METER CO., HEREFORD.

LOAVES THAT SELL.

To get the best Bread, the best colour, yield and size, add

"ANGLO-VIM" **to flour milled from English wheats or**

"PORT-VIM" **to flour milled from strong wheats or to imported flour.**

THE FRANKLAND MANUFACTURING Co.
(GREVILLE & CO.),
Head Office—Queen Insurance Building, Castle St.,
LIVERPOOL.

Specialists in products used in connection with flour.

BOOK OF BREAD, THE. By OWEN SIMMONS, F.C.S. (OWEN AND OWEN). 2nd Edition.

The illustrations in "The Book of Bread" are on an unparalleled scale. Lithography, colour process work, actual photographs, and photographic process illustrations have been employed in order that volume, colour, and texture of the various breads illustrated might be clearly indicated. In addition to half-tone illustrations in the text, there are 22 separate plates representing types of loaves—whole and sectional—two beautiful bromide photographs of Champion Loaves are included. The photographs and lithographic reproductions are mounted on art paper. A Special Circular will be sent free on application.

Ordinary Edition, **16/-** post paid. United States, **$5.75**; Australia and New Zealand, **22/6**; other countries, **20/-**.

MACLAREN & SONS, LTD., Publishers, 38, Shoe Lane, London, E.C. 4.

Books for Bakers.

	£	s.	d.
The Trade's Cake Book	0	13	0
The Book of Bread	0	16	0
Advanced Piping and Modelling	0	13	0
All about Biscuits	0	10	6
All About Gateaux and Dessert Cakes	0	13	3
All About Genoese Glaces, Petits Fours and Bon Bons	0	10	6
All About Ices, Jellies, Creams and Conserves	0	8	0
All about Pastries	0	10	6
Bakery Management	0	2	3
Baker's Guide to Book-Keeping	0	2	4
Book-Keeping for Small Traders	0	2	9
The British Baker's Selected Recipes	0	3	9
Cakes and How to Make Them	0	4	11
Catering by Confectioners	0	4	9
Cheap Biscuits and Cakes	0	2	9
Chocolate and Confectionery Manufacture	1	1	6
General Shop Goods	0	5	0
Suitable Goods for Hot Plates	0	2	2
Vienna and other Fancy Breads	0	3	9

The above prices include Postage.

Any of the Technical Works named in this list may be inspected at and obtained from the offices of

"The British Baker"

(MACLAREN & SONS, Ltd.),

38, SHOE LANE, LONDON, E.C.

DAVID THOMSON Ltd.,

EDINBURGH.

Telegrams—Bakery, Edinburgh.

Telephone—1438 Central.

COOK'S
"MATCHLESS"
CIRCULATING
STEAM TUBE
OVENS.
Perfect in every detail.
SMALL FURNACE.
Large Heating Area

We are the
ORIGINATORS of the
SMALL FURNACE
and the
PIONEERS of FUEL
ECONOMY
in Bakers' Ovens.

LOWEST FUEL CONSUMPTION.

STEAM HOTPLATES.
Fuel cost less than
ONE FOURTH
that of Gas Hotplates.

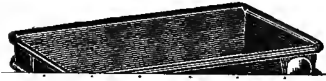
KNEADERS.
DIVIDERS.
HANGERS-UP.

DOUGH BRAKES,
CAKE MIXERS,
BISCUIT MACHINES

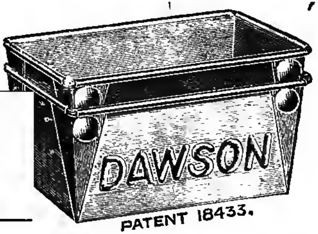
FULL EQUIPMENTS
TO SUIT ALL
CONDITIONS OF TRADE.
Plans and Estimates Free.

DATE DUE

APR 2 1 1948



STUDDED



Baking.
Baking.
use. No
oney savers.
E MADE.
post paid.

SON,

60, BURNETT AVENUE, Manchester Road, BRADFORD, Yorks.

'Phone—No. 427. 'Grams—"SEAMLESS." OUR PRICES ARE RIGHT. ESTABLISHED 1876.

TO OBTAIN THE BEST RESULTS

ALL BAKERS SHOULD USE

"EDME"

GOLD MEDAL

MALT EXTRACT.

MALT FLOUR.

"EDMEX"

The finest Improver in dry form.

"EDME" Gold Medal Yeast.

Write for Prices and Particulars—

EDME Ltd.,

BROAD STREET HOUSE, **LONDON, E.C.2.**

Telegrams—Edme, Ave., London. Telephone—5929 London Wall.

THE POWER BEHIND THE DOUGH.

"BITARTOL"

Finest Cream of Tartar Substitute.

THE BEST BY TEST.

100°/o ACIDITY.

Guaranteed to comply with the Local Government Board recommendations.

SUPPLIES IMMEDIATELY AVAILABLE.

PRESCOTT & Co.,

Rutland Mills,

Oswald Street, Hulme, Manchester.